HELLO STARS

Usha Srinivasan

HELLO STARS

USHA SRINIVASAN

National Council for S&T Communication,
Department of Science & Technology
Government of India
Technology Bhavan, New Mehrauli Road
New Delhi- 110 016

HELLO; STARS

This publication is an updated and modified version of NCSTC'S earlier publication `Getting Started in Sky Watching' by the same author.

Development & Compilation
Mrs. Usha Srinivasan, *Educational Consultant*

Editor in Chief
Dr. Narender K. Sehgal

Programme Coordinators
Dr. (Mrs.) Madhu Phull
Dr. D.K. Pandey

Layout, Design& Production Supervision
Ms. Sumita Sen
Ms. Sonu

ISBN: 81-7480-072-7
First edition: 2001
Second edition: 2003
Price: 45/-

Published by
National Council for S&T Communication,
Department of Science & Technology
Government of India
Technology Bhavan, New Mehrauli Road
New Delhi- 110 016

Distribution by
Vigyan Prasar
(An autonomous organisation under Department of Science &Technology)
C-24 Qutab Institutional Area, New Delhi -110 016
Printed in India by Nagri Printers, Shahdara, Delhi-110032. Ph. 22824217

Contents

INTRODUCTION

All human beings irrespective of age, colour, creed or sex have always looked at the twinkling diamonds in the sky and wondered about them—where have they come from? What are they made up of? How do they shine at night? The science of stars is considered a serious subject involving complex methods and mysticism. Perhaps for this reason Astronomy has not been given its proper place in the school syllabus. The objective of "Hello Stars" is to make Astronomy easy for beginners and especially youngsters. The inspiration for writing it has come from young school children who have shown great interest in stars, planets and events like the total solar eclipse. The book, in simple language, takes one from the known facts, beliefs and anecdotes to the scientific facts. The book has seven chapters.

The first is about the method of looking at the stars just as one locates a new city in an Atlas using the latitude and longitude. Experience in the schools has demonstrated beyond reasonable doubt that this approach kindles the fire of interest in young minds apart from giving them the thrill of achievement.

The second chapter describes the mythological stories (Indian and Greek) about the zodiacal constellations and their importance. These stories have been passed on from generation to generation and help remember the shapes of these constellations and their relative positions in the sky.

The third chapter deals with star charts and maps. The first part deals with the prominent constellations in the northern and southern hemispheres and the second part with the seasonal maps viz. winter, spring, summer and autumn. This chapter continues with mythological stories about these stars and constellations to facilitate their location and identification in the sky.

These chapters help in finding one's way in the sky using simple star maps, unaided eyes and parts of our hands as sighting devices. It also deals with observations using telescopes. Chapter Five describes the relationship between the festivals such as Diwali, Easter, Baisakhi etc. and the precise movements of the sun, moon and stars in the sky by day and night. Festivals like Diwali, Eid etc. are celebrated on particular days once a year, but the Kumbh mela is held only once in twelve years. The why and how of these events is brought out in this chapter.

After having created adequate enthusiasm and curiosity the Sixth chapter is devoted to the ancient wisdom that prevailed in India and the evolution of Astronomy in India. Without modern aids our ancient star gazers were able

to device a lunar calendar as early as 1182 B.C. The yantras in the Jantar Mantar based as they are on the ancient astronomical knowledge of India have been used for making accurate and complicated astronomical observations and calculations. The method of using some of these instruments have been explained with the help of simple and detailed diagrams.

In chapter Seven, an attempt has been made to take one through calculations and deductive logic to see why some stars appear brighter than others and to know more about their constituents and classifications.

This section brings smaller versions of the Yantras (instruments) from the Jantar Mantars to you. The purpose is to describe the simple models which have been developed with the specific purpose of enabling readers to understand the concepts. By this method difficult and abstract concepts have been made clear. Special care has been taken to design these models with materials which are cheap and easily available. The emphasis is on learning the concepts through a process of leisure activities.

These models are representative of the available potential of such a method of learning. Each model can be easily modified according to the need of the user. The intended catalytic effect will go a long way in achieving the objective of knowing more about the stars and the sky.

If after reading this book, the readers feel star friendly and desire to know more about them, I would consider that the objective of this book has been achieved.

Usha Srinivasan

Usha Srinivasan

CHAPTER 1
The Night Sky

The fields of flowers in bloom, rainbows, water falls, the view of the night sky filled with stars—scenes so beautiful and breathtaking! Since a long time, the stars have been used for finding time, maritime navigation and have also formed a basis for mythological stories. Astrologers made use of them to predict our future. Poems and nursery rhymes have been written on stars, moon and the night sky. some stars were named after saints and famous people. You know the story of a boy, named *Dhruva*. In order to get his father's love, he prayed to god with perseverance and patience. He won his father's love. So a star which seems to be stationary in the sky, as seen from the earth was named after *Dhruva*. *Dhruvtara* is also called pole star.

On a clear night, we in the Northern hemisphere can see around 3000 stars with naked eyes. From the southern hemisphere, almost the same number of stars are seen. While looking at the clouds in the sky, you must have imagined figures of birds, snowman, animals etc. similarly, when people looked up at the night sky, they connected some bright stars and made patterns of animals, birds, kings, queens, hunter etc. and wove numerous stories about them. The area occupied by each of these patterns is called a constellation (fig.1). The entire sky is divided into 88 constellations. They are:

Andromeda	Circinus	Lacerta	Piscis Astrinus
Antila	Columba	Leo	Puppis
Apus	Coma Berenices	Leo Minor	Pyxis
Aquarius	Corona Australis	Lepus	Reticulum
Aquila	Corona Borealis	Libra	Sagitta
Ara	Corvus	Lupus	Sagittarius
Aries	Crater	Lynx	Scorpius
Auriga	Crux	Lyra	Sculptor
Bootes	Cygnus	Mensa	Scutum
Caelum	Delphinus	Microscopium	Serpens
Camelopardalis	Dorado	Monoceros	Sextans
Cancer	Draco	Musca	Taurus
Canes Venatici	Equuleus	Norma	Telescopium
Canis Major	Eridanus	Octans	Triangulum
Canis Minor	Fornax	Ophiuchus	TriangulumAustralis
Capricornus	Gemini	Orion	Tucana
Carina	Grus	Pavo	Ursa Major
Cassiopeia	Hercules	Pegasus	Ursa Minor
Centaurus	Horologium	Perseus	Vela
Cepheus	Hydra	Phoenix	Virgo
Cetus	Hydrus	Pictor	Volans
Chamaeleon	Indus	Pisces	Vulpecula

Rhythms in the sky:

Ancient people all over the world found that there were distinct rhythms in the sky. One was the rising and setting of the sun -- a rhythm which repeated itself every 24 hours. The other was the changing shape of the moon in the sky, from full moon to new moon and back to full moon again. The change in position of moon daily was studied against the backdrop of 27 Nakshatras (stars and star clusters). These are also called lunar nakshatras (or *janma nakshatras*). They are *Aswati, Bharani, Karthigai, Rohini, Mrighaseesham, Thiruwadirai, Punarpoosam, Poosam, Ayilyam, Makam, Pooram, Uthiram, Hastam, Chithirai, Swati, Vishakam, Anuradha, Jyeshta, Mulam, Pooradam, Uthradam, Thiruvonam, Avittam, Sathayam, Pooratathi, Uthiratathi* and *Revathi*. The third rhythm is annual. This is due to the revolution of earth around the Sun.

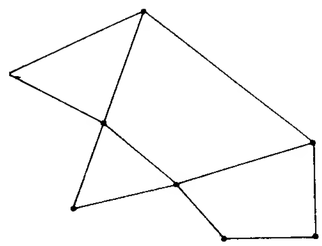


Fig. 1 Sagitarious Constellation - Teapot

Our own Sun is a star! It is the nearest star and of course the brightest seen from the earth. For us the Sun is the most important star and is the chief source of energy, light, heat and life. It is the only star that we can observe and explore at hand in detail.But the Sun is not particularly outstanding amongst the thousands of millions of stars.

Do all the stars rise and set? Just like our Sun rises in the east and sets in the west, stars also appear to rise in the east and set in the west. This is due to the rotation of the earth around its axis from west to east. The stars seem to rotate around on axis. This axis passes through North and South poles of earth and the pole star. The earth's axis points towards the pole star i.e. the North celestial pole. So when we face the pole star, we are facing North. (fig.2)

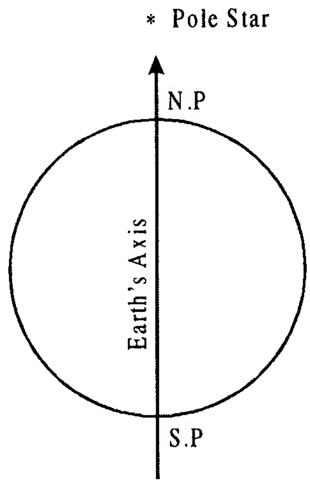


Fig. 2

Precession:

Like the spinning top that rotates on its own axis while slowly turning about the vertical, earth's axis also changes its direction. This motion is called precession. The earth's axis describes a cone about a point in space called the pole of the ecliptic (about which we will read later in the chapter) and the result is the slow movement of the northern celestial pole describing a circle of 23.5° round the pole. The axis completes one circle in about 26,000 years. Do

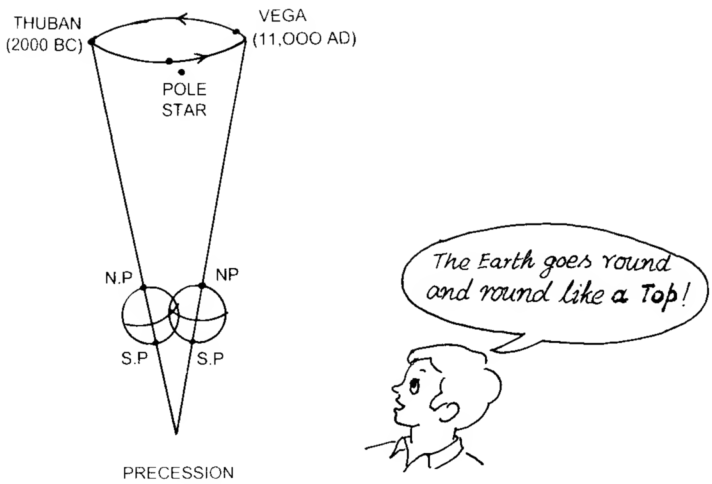


Fig.3

you know? In 2000 BC, the star called Thuban was our pole star and in 11,000 AD, a star, Vega will be our pole star (fig.3)

We can see the pole star through the night everyday, but not all the other stars all the time. If you see a star at zenith at 8:00 P.M., then at 12 mid night the same star would not be seen at the zenith, but somewhere down in the west.

As the earth rotates and revolves each day, the stars appear to rise four minutes earlier than the previous day. So the constellations that we see tonight might not be seen six months later.

How can we know the location of the stars and constellations in the sky? Can we find out when and where a particular constellation would be on a particular day? To get the answers to these questions, let us make use of a special globe, the celestial globe.

You want to locate a city. What do you do? Refer to a globe or map. If the latitude and longitude of the city are known, you can easily locate it. Try it. Locate the city whose longitude is 75°W and latitude is 40°North. Try finding out the latitude and longitude of Delhi using your atlas. Just the same way, by using sky maps, star charts or the celestial globe, we can locate a star.

Celestial Globe

What is a celestial globe (also called celestial sphere)?

Imagine the earth to be at the centre of a huge black sphere, stars being studded on this imaginary sphere. This sphere of infinite radius is called the celestial sphere. If you extend the axis of the earth in both directions, it would pass through the North pole and South pole of the celestial sphere too. The celestial equator is parallel to the earth's

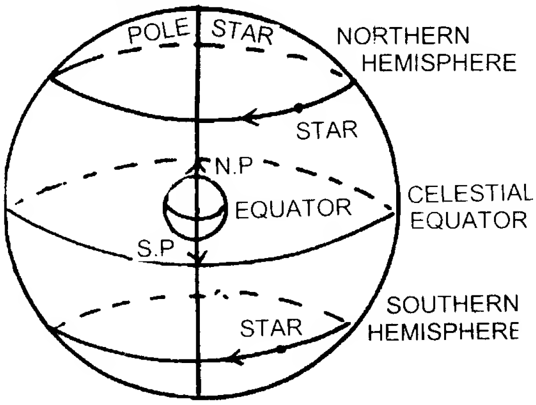


Fig. 4

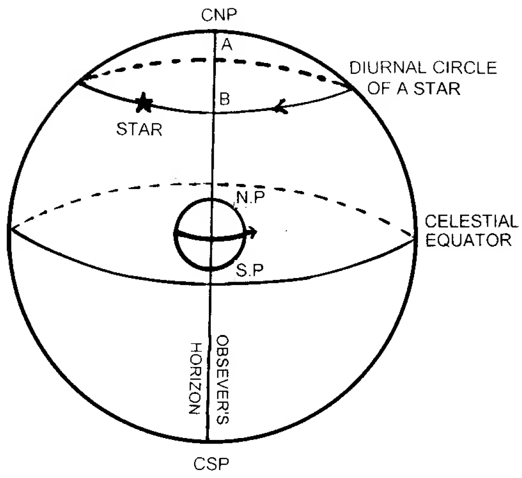


Fig. 5 Star Appears to Rise At A and Set At B

equator and is also in the same plane. The celestial equator also divides the celestial sphere into two halves, the northern and the southern hemisphere (fig.4).

When you stand either at the North or the South pole and look up at the night sky, the stars would appear to move about the Zenith in concentric circles. Here there would be no rising or setting of stars. The path taken by a star on the celestial sphere is called its Diurnal Circle (fig.4).

But if you stand at the equator, the celestial equator would be over head and the stars would seem to rise in the east and set in the west, their paths would be perpendicular to the horizon. Where would the pole star be seen? (fig.5).

If you stand at any other place, say Delhi (longitude 77.20°E and latitude 28.65°N), the pole star would be seen at an altitude which is equal to the latitude of Delhi. You draw a line making an angle equal to 90°-latitude of the place i.e. (90°-28.65°) with the celestial axis or an angle = latitude of the place i.e. 28.65° with the celestial equator. This is CY. The stars to the north of the Diurnal Circle CD would be seen throughout the year. These are called circum-polar stars. The stars of the Ursa Minor constellation are circumpolar stars. But the stars to the south of the Diurnal XY would not be seen at all from Delhi (fig.6).

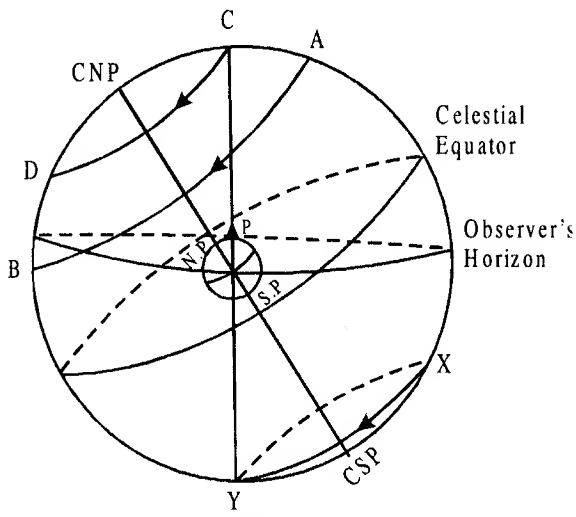


Fig. 6 Observer is at P

Ecliptic: The earth's axis is tilted at an angle of 23.5° from the perpendicular to the plane of earth's orbit. So the Sun's path on the celestial sphere is also tilted at an angle of 23.5° to the celestial equator. The apparent path of the Sun is called the Ecliptic or the Rajpath(fig. 7)

Sun and all the planets (except Pluto) of the Solar system are almost on the

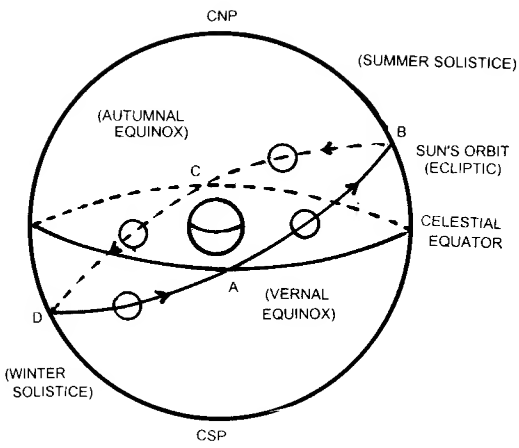


Fig. 7

same plane. When we look at any of these planets from the earth, we are always looking along the same plane. So the stars forming the background to these planets also lie on a narrow belt extending above (North) and below (South) the plane. These background constellations, are called the Zodiacal constellations.

The 12 Zodiacal Constellations (called the 12 Rashis) form the East-West belt of width 18°, 9° to the north and 9° to the south of the Ecliptic. The Sun appears to move from one constellation to the next in the span of one month.

Earth's orbital period around the Sun=12 months.
Number of Zodiacal Constellations = 12
The time taken by the Sun at each constellation = 12/12=1 month

This belt forms the backdrop for the Sun, moon and the planets of our solar system (as seen from the earth). So these constellations which form the Zodiacal belt are very important.

●●●

CHAPTER 2
The Zodiacal Constellations

The Zodiacal Constellations are : Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius and Pisces (fig.8).

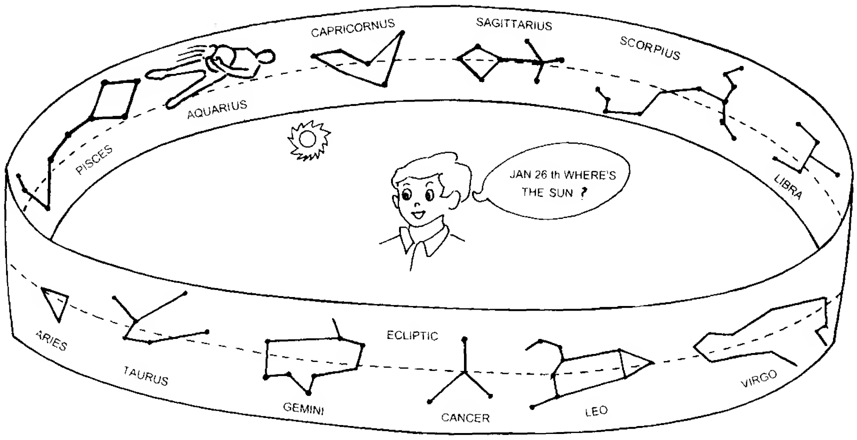


Fig. 8 The Zodiacal Belt

The celestial equator and the ecliptic intersect each other at 2 places (A and C in the figure). These correspond to Vernal equinox (March 21 and Autumnal equinox (September 23). The points B and D correspond to Summer solistice (June 21) and winter solstice (December 22) in the Northern hemisphere (fig.9).

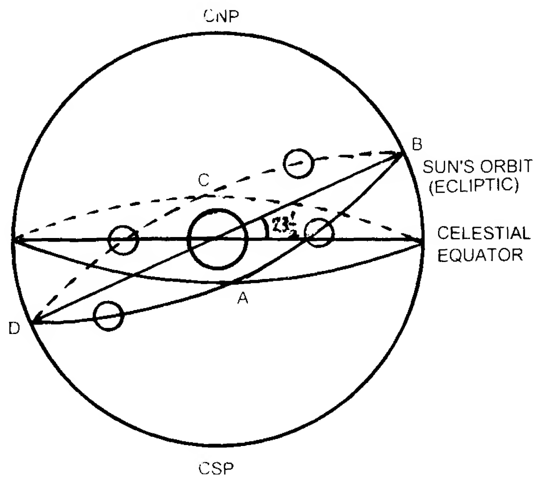


Fig. 9

On vernal equinox and autumnal equinox, the days and nights are equal in length. June 21st is the longest day and December 22nd is the shortest day in the Northern hemisphere.

From C to D, the Sun seems to move southwards. At D Sun seems to change its direction, i.e., it seems to move from South to North. This is Uthirayan.

From A to B, Sun seems to move in the South-North direction and at B, it again seems to change its

direction to North-South direction. This is called Dakshinayan. Let us start our journey along the Zodiacal belt.

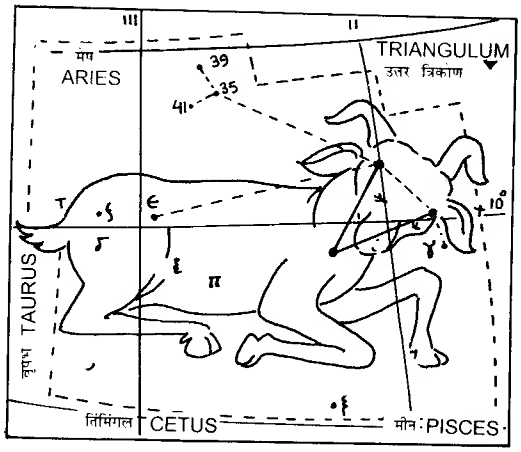


Fig. 10 Aries

Aries: Let us start with position A, where we find the first Zodiacal Constellation Aries (the Ram). The Indian name is *Mesa*. In Indian Astronomical conception, the constellation is considered as 'Aswini' (Aswamukha, i.e., like horse's mouth). In vedic literature, Aswini is described as being anxious to learn *Madhu Vidya* from Sage Dadichi. Indra threatened Dadichi that he would chop his head off if he taugh his skills. Aswini suggested that the head of Dadichi which contained all the knowledge could be removed and in its place a horse's head be placed. So when Indra cut Dadichi's head, it was only the horse's head that was removed and not Dadichi's head which was full of knowledge.

But according to Greek mythology, Aries, the Ram could fly and was covered with a golden fleece. This ram was bought by Mercury for the king of Thessaley's two children and was given a place in the sky.

Look up at the sky and look for a shape similar to a horse's mouth or a goat's face and that is Aries constellation. (fig.10).

Taurus, the bull : Taurus (*Vrishaba*) occupies a very important and prominent place in most of the ancient cultures. Mohenjodaro represents civilization prior to the vedic period. A horse with a horn, an elephant and a bull were common pictures in those times. Coins also carried impressions of a bull. Among Lingayas, the bull is regarded as incarnation of God. The brightest star of this constellation is called Aldebaran (Indian name is *Rohini*). This star is the eye of the bull. It is a red coloured star. According to Chileans, Taurus represents an illuminated bull, which collided against the Sun and caused the onset of spring. In the ancient times, i.e. around 4550 BC to 1850 BC, Vernal equinox was actually in Taurus. (fig.11).

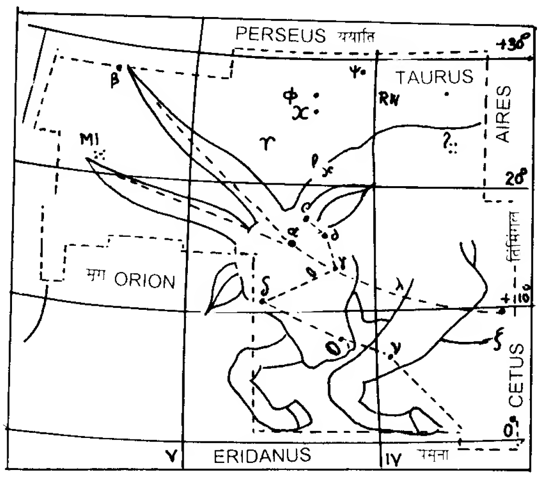


Fig. 11 Taurus

According to Greek Mythology,

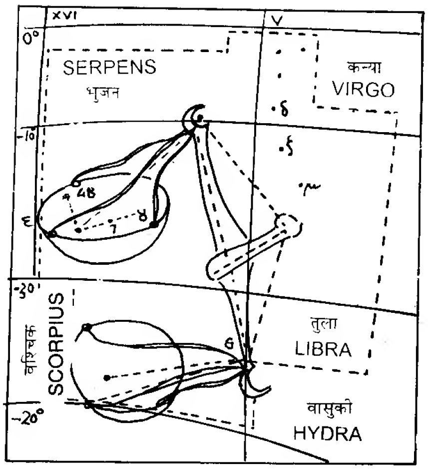


Fig. 16 Libra

Libra, *Tula*: The ecliptic meets the celestial equator at 2 points known as equinoxes. The autumnal equinox (September 22) coincided with the entry of the Sun in the constellation, Libra. Hence the name Libra, the balance. The constellation resembles a beam balanced with scale pans. The scales indicated the equality of day and night. But now, the autumnal equinox has shifted to Virgo. Star *Vishakha* (Zubenel Getnubi) is the brightest star of the constellation. (fig.16)

Scorpius, *Vrichika* : This constellation is easily recognisable as it closely resembles the shape of a scorpion.

According to Indian mythology, the four bright stars in the claws and mouth of the scorpion, make the *nakshtras* of *Vrishaba* and *Anuradha* respectively. The body of the scorpion with its three bright stars constitutes the *nakshatras Jyeshta* (or Kettai) and the nine stars in the curve forming the sting constitutes the *Nakshtra* of *Mulam*.

The bright star of this constellation is a huge red star called Antares (*Jyeshta*). The other prominent ones being Zuba (*Anuradha*) and Shewla (*Mulam*).

According to the Greek legend, this is the poisonous scorpion that stung the mighty hunter Orion. Instigated by Juno, the Scorpion stung Orion's heel. But later, Juno felt bad about the incident and arranged to have the Orion and the scorpion placed among the stars (fig.17).

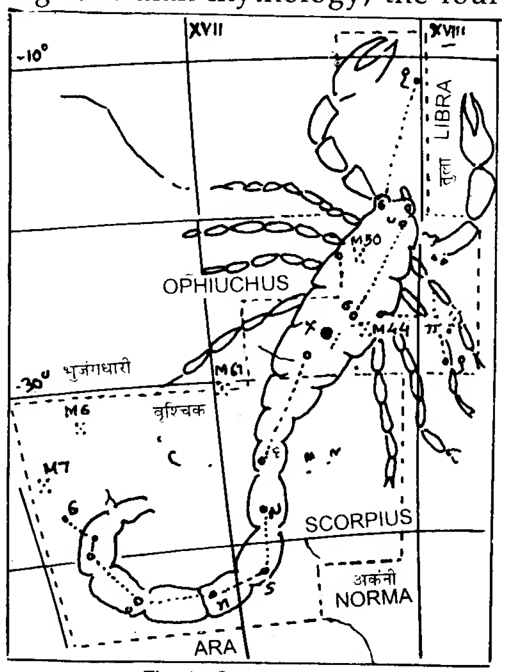


Fig. 17 Scorpius

Sagittarius, *Dhanu* : The centre of our galaxy lies in the constellation, Sagittarius. The Sun passes through it from mid December to mid January and the winter solistice lies here. It is at the most southernly part of the ecliptic.

According to Greek mythology, Sagittarius, the Archer is supposed to be a centaur. The centaur has the body of a horse and head and shoulder of a man.

The bright stars of this constellation can be joined in different ways to form different figures. It looks like a tea pot and some time like a centaur whose arrow points towards the bright star, Antares of Scorpius. (fig.18)

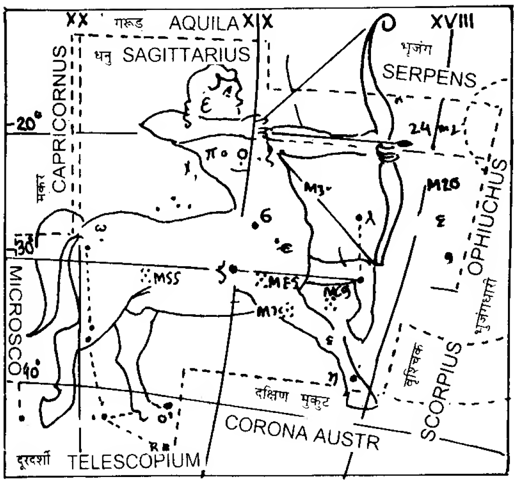


Fig. 18 Sagittarius

Capricornus, the goat : It lies in the southern half of the ecliptic and is not a very conspicuous constellation. According to legend Capricornus, the goat, was placed among the constellations to commemorate the adventure of the god Pan. In a fight with a monster, Typhon, everybody ran away in panic. But Pan along with others jumped into a river and were transformed into two fishes and sea goat. This sea goat is Capricornus and the two fishes formed the constellation Pisces.

There is another version of the legend. When Greek nymphs and goddesses were bathing in river, Pan wanted to make fun of them. He became a goat and jumped into a river. When he did this, the part of the body submerged in water took the shape of the fish while the upper half remained that of the goat.

The constellation does look like half goat and half fish (fig.19). The Indian name for Capricornus is *Makar*. Some 1400 years ago, Sun used to be in this constellation when passing through the southern most part of the Ecliptic known as winter solistice, which falls on 22nd December. But at present, Sun enters *Makara* constellation in the third week of January instead of 22nd December. Hence 23½^0 south was called Tropic of Capricorn. This shift is because of precession. The festival of *makara Sankarati* gets the name from the constellation.

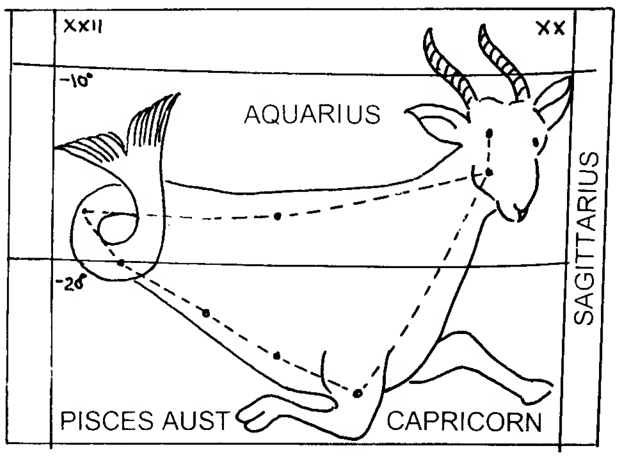


Fig. 19 Capricornus

Aquarius: This constellation lies to the east of Capricornus. The name Aquarius means the water-bearer and the origin of this name is believed to be in one legend from Greek mythology. Jupiter sent an Eagle (Aquila) to kidnap a beautiful shepherd youth named Ganymede. The youth was carried to the abode of Gods against the wishes of his father. In this affair, Jupiter consoled the grieving father of Ganymede by giving him a pair of divine horses and rewarded Ganymede by placing him as the Aquarius (the cup bearer) constellation. It is believed that the cup contained Nectar and not plain water.

The legend in Indian mythology of 'Churning of the Ocean" (*Samudra*

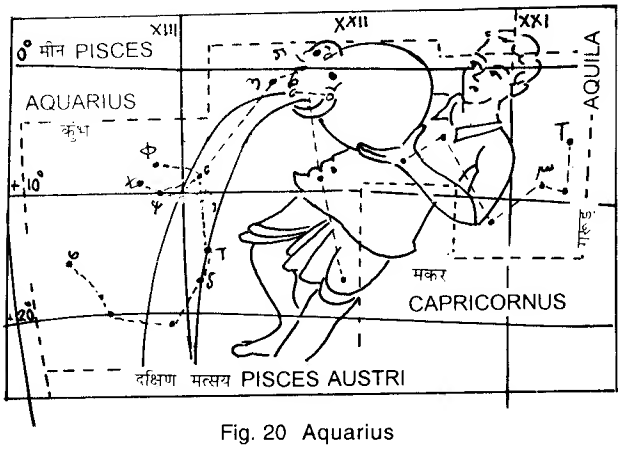


Fig. 20 Aquarius

Capricornus (Sea-Goat) Aquila (the eagle) and the Hydra (the sea snake) are the participating constellations, the sea snake forming the rope around the churning pillar in the legend.

At present, the Sun happens to be in Aquarius during the month of February. But in a previous epoch, when the Sun occupied this position for observers from Mesopotamia, it was the rainy season and probably that explains the pictorial representation of Aquarius. The picture looks like, some one emptying a vessel full of water on the neighboring Pisces (fish fig.20).

Pisces: It means fish and is a conspicuous constellation. According to the Greek legend, a giant called Typhoon made his appearance on land and frightened even the Gods who fled to river Nile and hid themselves under assumed shapes. Jupiter changed himself in to a Ram (Aries), Pan took the form of a sea goat (Capricornus) and goddess Venus and her son Cupid jumped into the river and changed themselves into two fishes. The shape of the constellation Pisces looks like two tied up fishes (fig.21).

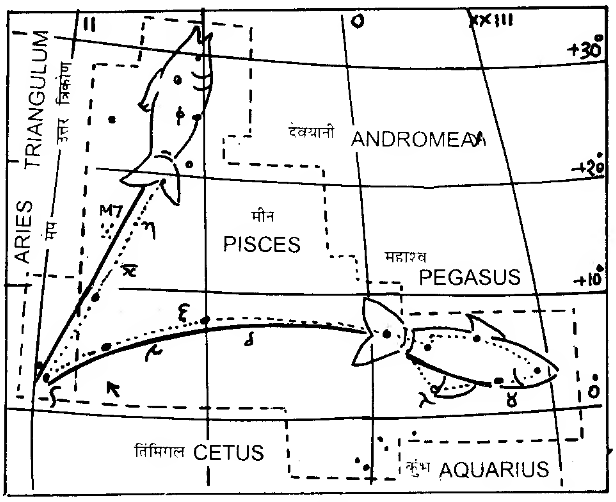


Fig. 21 Pisces

In India, it is called *Mina* (*Rasi*). The seven stars of this constellation, when connected make up a polygon with seven sides. Starting from the left hand side top (head of the fish) move down left to its tail, the other fish resembles a kite flown with a string starting from a bright star, called *Kaitaim.*

A group of stars in this constellation is called *Revati.* In Indian astronomy *Revati* is one of the 27 Nakshtras.

These stories will help you remember their shapes and positions in the night sky.

●●●

CHAPTER 3
Let us Make Friends With Stars

The bright twinkling stars challenge you to fit any pattern that you can imagine and weave your own stories about them. As I told you earlier, there are many mythological stories attached to these stars and constellations. The sky is a huge story book! In the previous chapter, you read about the zodiacal constellations. Let us open the story book and read on about other stars and constellations.

Let us start with *Dhruvtara* (pole star). How do we locate it in the sky? Constellation Ursa Major help us. It is an easy constellation to identify. There are 7 bright stars, four of them making a quadrangle and 3 others making a trailor, a handle or a plough. The 7 stars form parts of a big bear in the sky, called the great bear. The 4 stars are in the body of the bear and the 3 others make the tail. The other faint starts making the rest of the body and the face of the bear (fig.22)

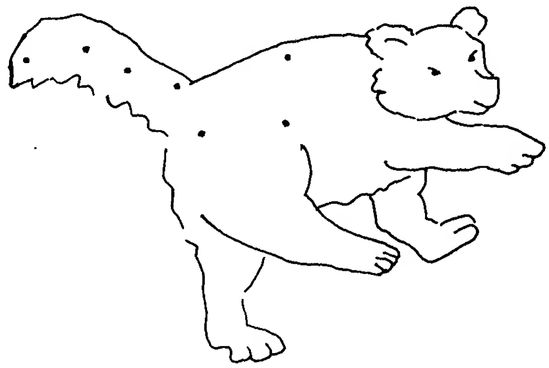


Fig. 22 Ursa Major - The Great Bear-Saptarshi-Great Dipper

According to Indian mythology, Ursa Major is called 'Sapta Rishi' or seven sages. The sages - *Kratu, Pulaha, Pulasya, Atri, Angira, Vasishta* and *Marichi* find a place of prominence in the sky.

But during winter, we have to look for some other constellation to locate the pole star as Ursa Major is a summer constellation. From October to March, we can use 'Cassiopia' constellation. Five bright stars of this constellation make the letter M or W of the English alphabet. In ancient mythology, Cassiopia was an Ethiopian queen. She was very beautiful and very proud. she disregarded the sea nymphs. To display her contempt for them she placed her throne on the sea shore. As a result of general discontent, God ordered that Cassiopia's chair would always appear in the tilted fashion. Doesn't it look like a tilted chair? In Indian Astronomy, it is called *Sarmishta* (fig.23)

When you extend the line joining the pointer star of Ursa Major, it points to the pole star. The line bisecting the bigger angle of the "W" of Cassiopeia also points to the pole star (fig.23).

Cassiopia and Ursa Major also make a good celestial clock. We have located the pole star and so we have got our orientation. What next? The whole sky is

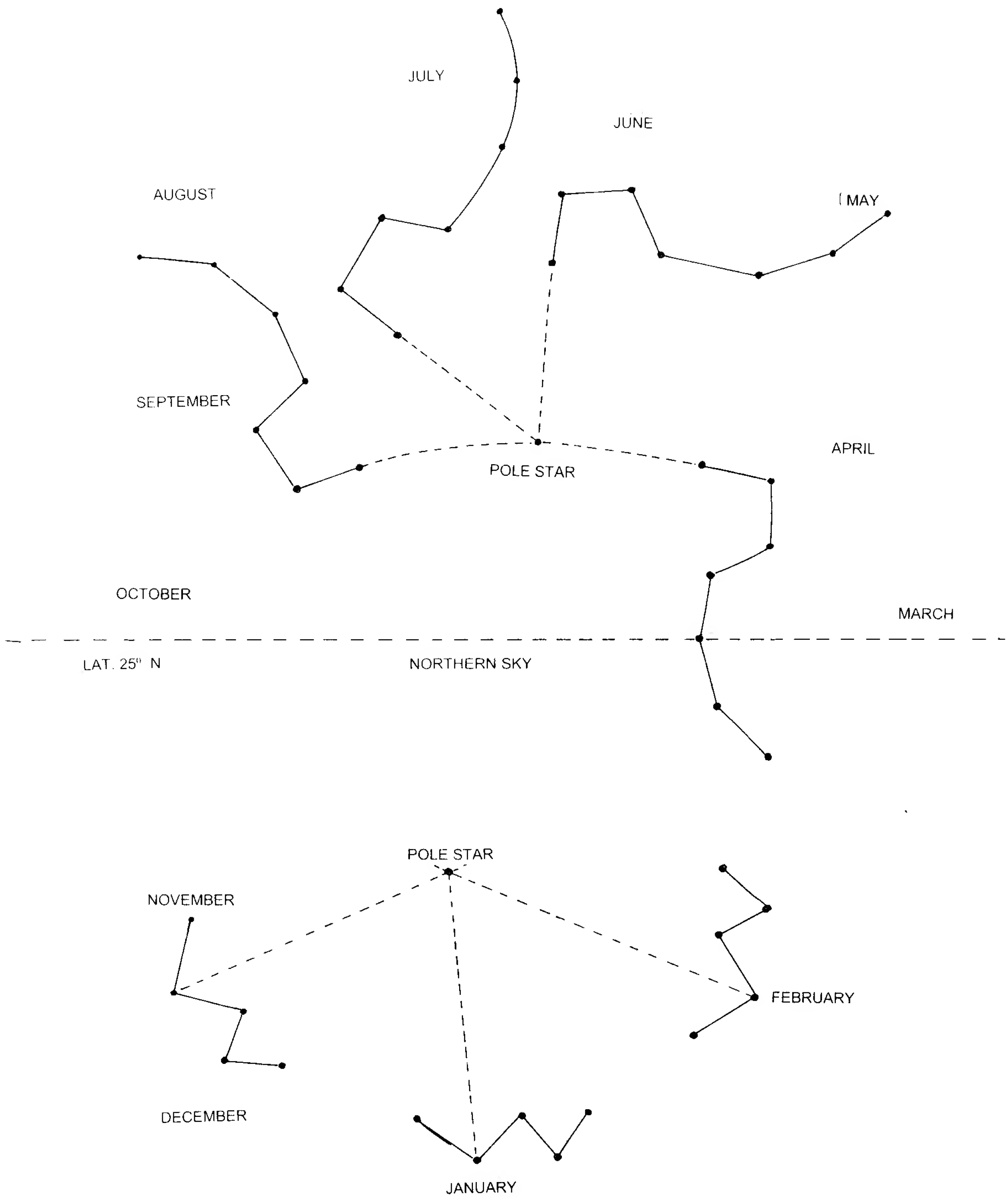


Fig. 23 Identify the Pole Star with the help of Ursa Major and Cassiopia

there for us to explore.

Let us first learn about latitudes and longitudes of stars on the celestial globe, which will help us in locating stars, constellations and other heavenly objects.

Latitudes and Longitudes on Celestial Globe

Declination and Right Ascention of a star

Latitude on the celestial sphere is called declination and longitude is called Right Ascention. The circle drawn from celestial North Pole through the star is called its hour circle. The longitude of a star is the angle between its hour circle and the position of Vernal equinox, measured in the anticlockwise direction i.e., opposite to the direction of dirunal. Celestial equator is divied into 24 hours, each hour into 60 minutes and each minutes into 60 seconds. Latitude or Declination of a star is its angular distance from the celestial equator. Declination and Right Ascention of a star remains the same, wherever we are on earth (fig.24).

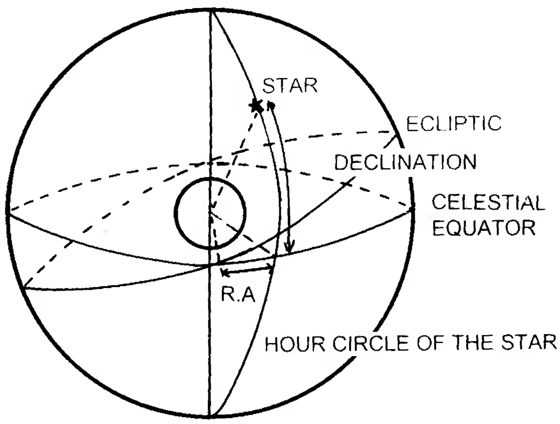


Fig. 24

A star which is at the position of Vernal equinox would have Right Ascention of 0^0 and declination of hour angle XXIV or 0^0.

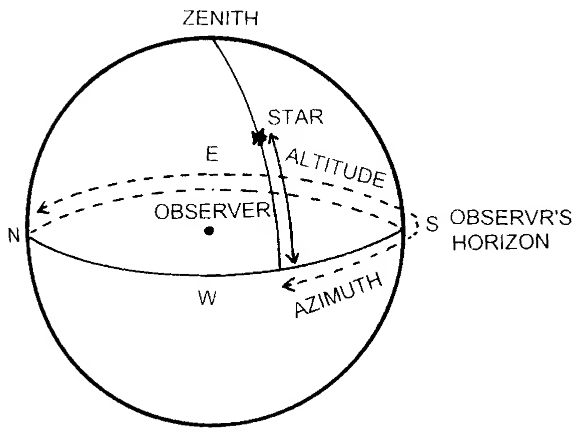


Fig. 25

Horizon System

Do you want to know a local system? The local system is called the horizon system. The height of a star from the observer's horizon is called its altitude. If you are standing at Delhi, the altitude of pole star would be equal to the latitude of Delhi i.e. 28.65° (fig.25).

The angular distance between the star and pole star (measured

eastwards) as viewed by the observer is called Azimuth. Wherever you are, Azimuth of pole star is zero. Altitude and Azimuth of other stars depend upon the observer's position on the earth.

Star Maps

You are given a set of four sky maps to help you. They show the constellations around the Northern celestial pole, constellations around the Southern celestial pole and those between hour angle 24 (XXIV) and 12 (XII) and between 12(XII) and 24 (XXIV). Refer to the maps and locate the important constellations which are also visible to the unaided eye.

In the figure showing the North Polar chart, you can see the constellations around the pole star(fig. 26).

1 is Ursa minor whose tail end is pole star. From 1, move to 2, Ursa Major and 3 is constellation Auriga. Then move to Perseus (4), to Cassiopeia (5), to Cygnus, the Sqan (6), to Bootes (7), Leo (8), Cancer (9), Gemini (10), Taurus (11), Aries (12), Pisces (13) and to Pegasus (14). Some of these constellations are seen completely in the star charts showing the constellations on both sides of the celestial equator from hour angle 0° to XXIV.

In the next figure of south polar star chart, the constellations around the South pole of the celestial globe are shown. There is no pole star in the southern hemisphere. Some of the important constellations are Scorpius (15), Sagittarius (16), Pisces Austa, the southern fish (17), Phoenix (18), Centaurus (19), Canis Major (20) and Crux, the southern cross (21)(fig.27).

The next two star charts show the constellations from hour angles XXIV to XII and XII to XXIV respectively.

Hour angles XXIV to XII : From Pegasus (14) move to Cygnus (6), Hercules (22), Bootes (7), Virgo (23), Libra (24), Equuleus, the serpent bearer (25), Aquila the eagle (26), Aquarius (27), Capricornus (28), Sagittarius (16), Scorpius (15), Centaurus (20), Telescopium (29), and Pisces Aust (17) (fig. 28).

Hour angles XII to XXIV : start from Ursa Major (2), move to Auriga (3), Perseus (4), Andromeda (30), Aries (12), Taurus (11), Gemini (10), Cancer (9), Leo (8), Orion (31), Pisces (13), Phoenix (18), Canis Major (19) and to Vela, the sails (32)(fig.29).

The four star charts show the imaginary figures representing the constellations. The next set of 4 sky maps are of winter, spring, summer and autumn, which help you identify some of the important and prominent constellations of the respective seasons.

Winter Sky

In the winter sky, you can see a band of 3 bright stars. They belong to constellation 'Orion', a prominent constellation of the winter sky. It is also called 'hunter" and the band of 3 bright stars forms the belt. The star on the shoulder of Orion is '*Ardra*' or 'Betelgeuse' while the one near the knee is '*Rajanya*' or 'Rigel'. When you go straight down, about four times the length of the belt, you will find the brightest star of the sky—Sirius in the constellation

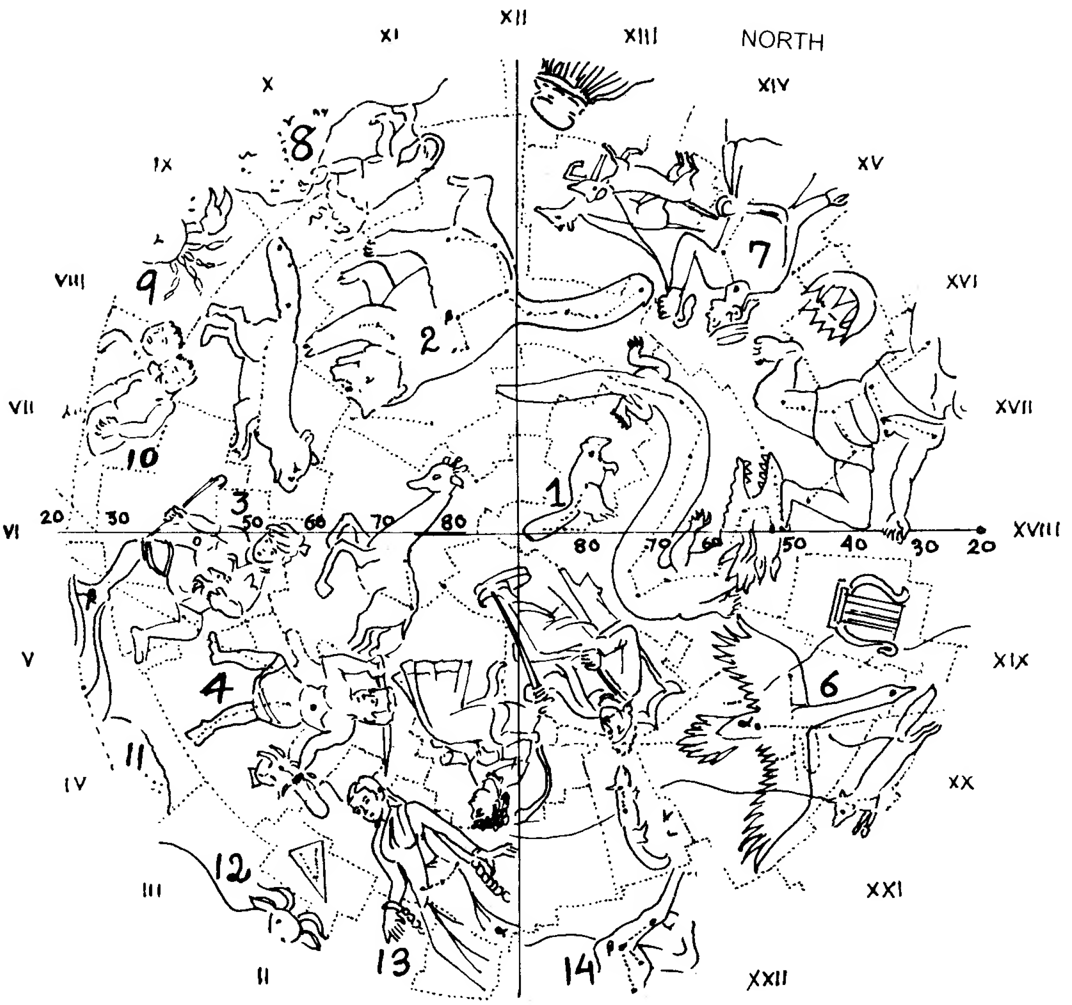


Fig. 26 North Polar Star Chart
(imaginary figures of constellation)

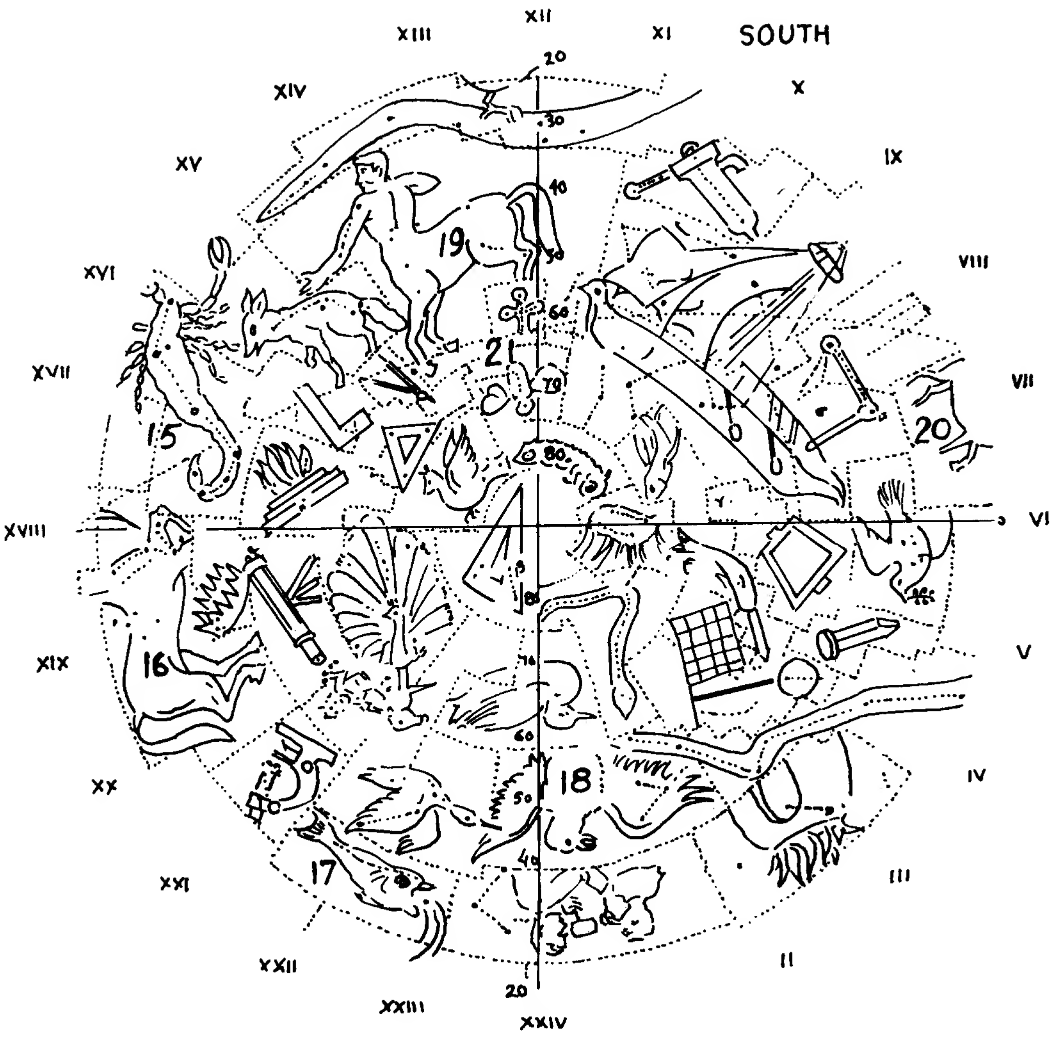


Fig. 27 South Polar Star Chart
(imaginary figures of constellation)

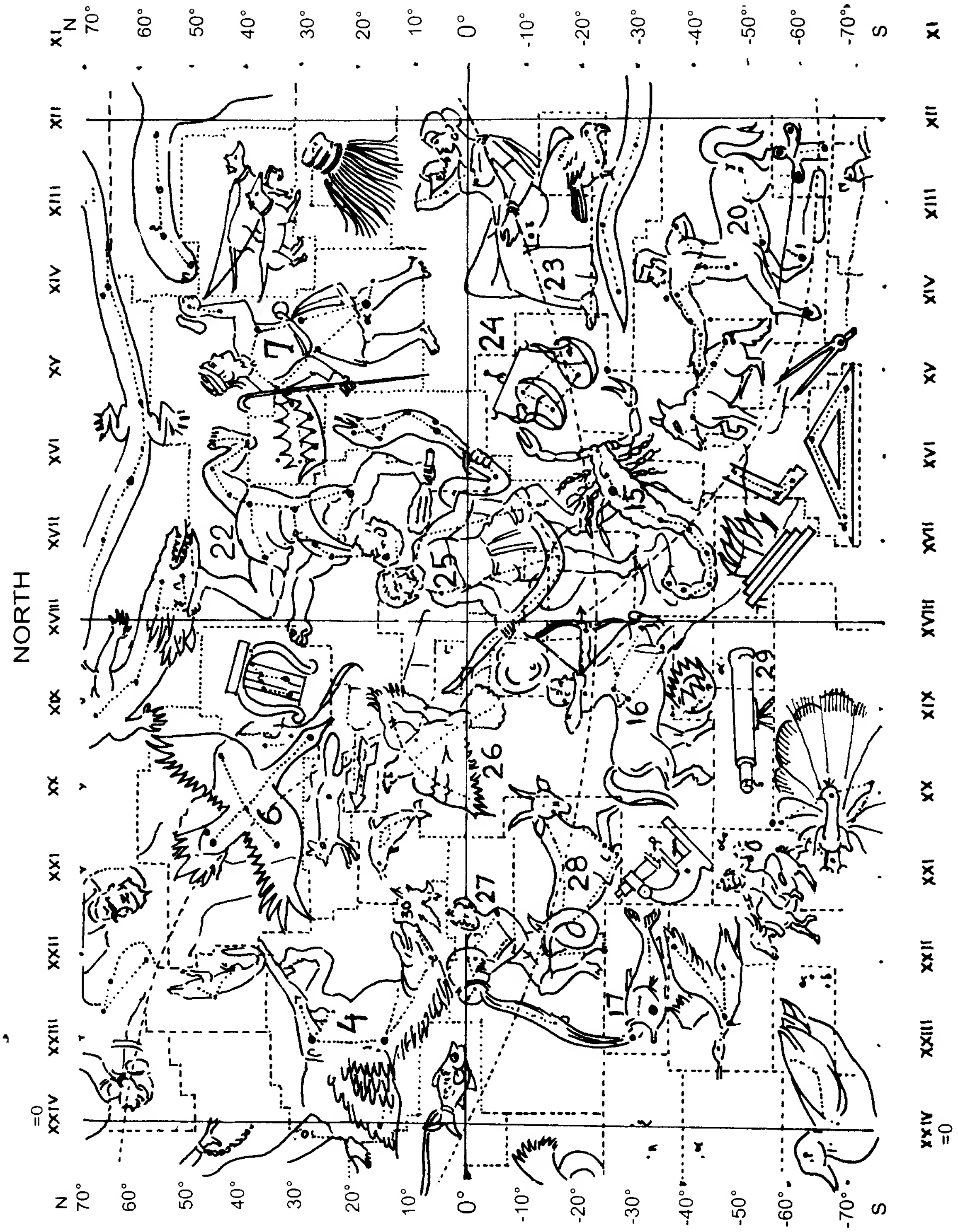


Fig. 28 Equitorial Star Chart Showing Imaginary Figures of Constellations on Both Sides of Equator(Celestial)- Hours Angles XXIV to XII

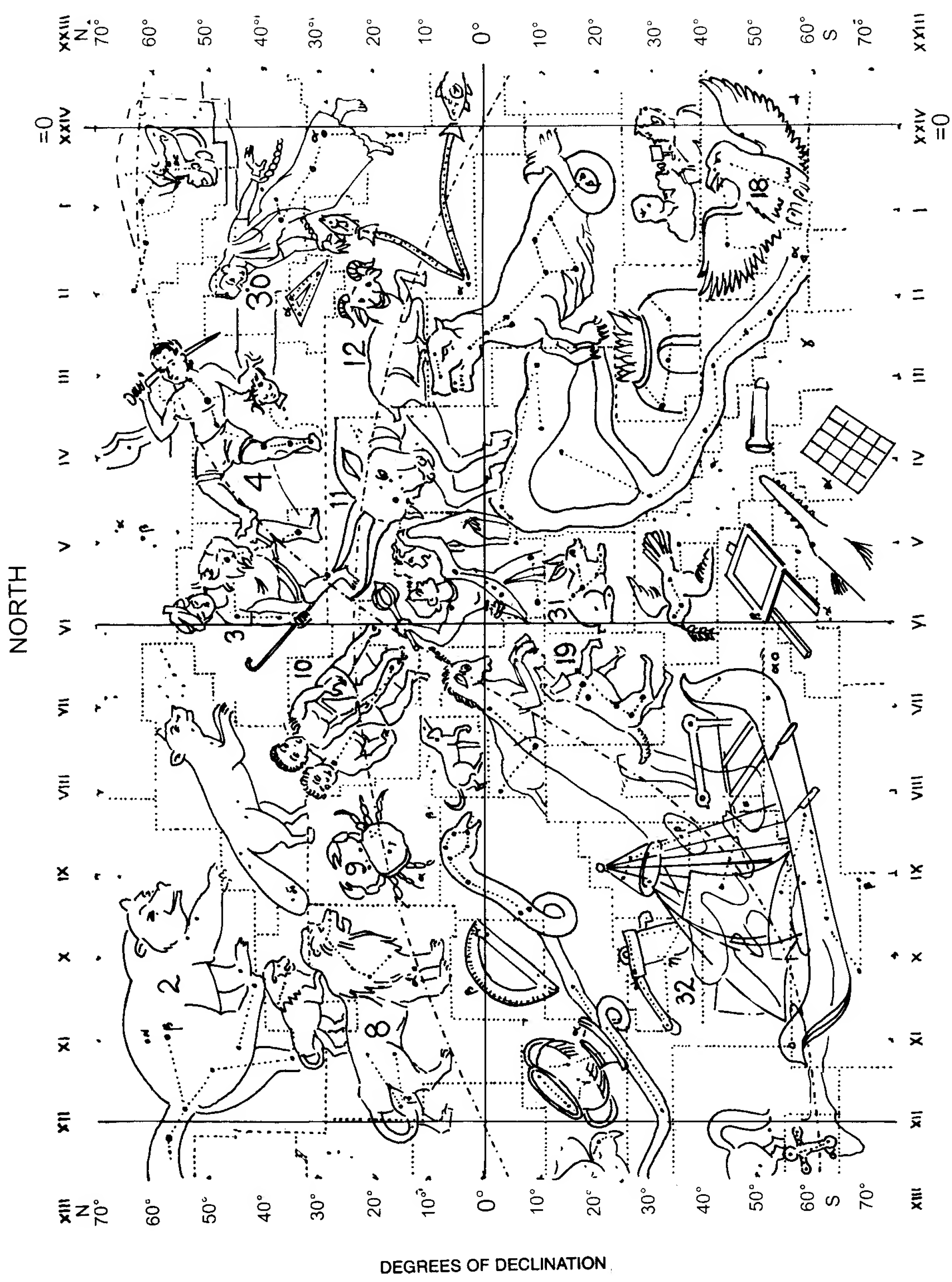


Fig. 29 Equitorial Star Chart - Hour Angles 0 to 12 or between XII and XXIV

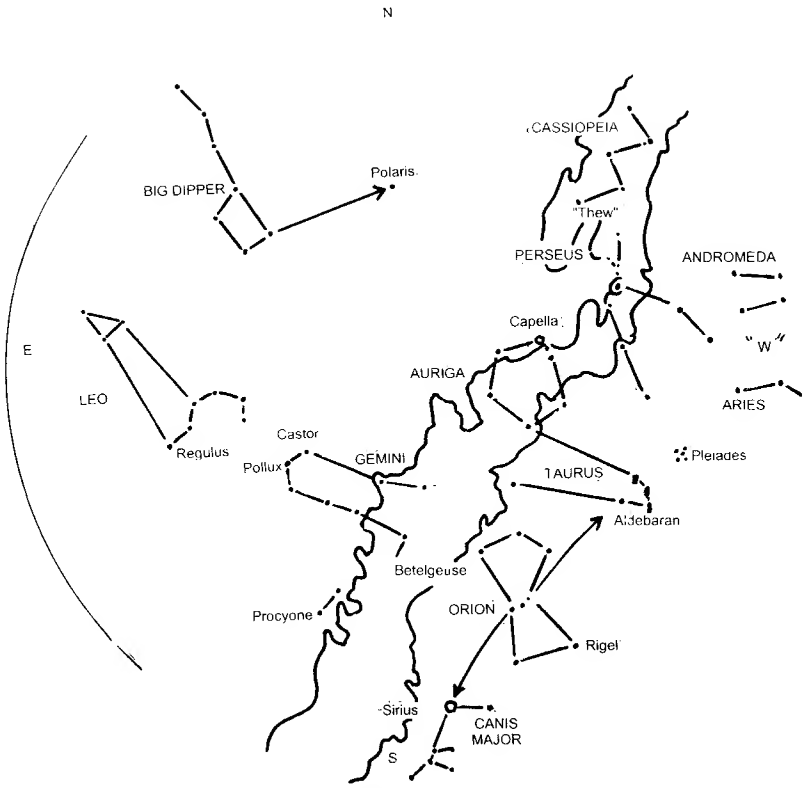


Fig. 30 The Stars of Winter

'Canis Major'. If you go in the opposite direction, you will see a bright red star - Aldebaran in the constellation 'Taurus'. (fig.30)

The reddish Aldebaran belongs to the interesting zodiacal constellation Taurus. The V-shaped constellation forms the head of the bull. The Indian name is *'Vrishabha'*. Around 4000 years ago, Vernal equinox was in the Taurus constellation. This constellation includes two star clusters, 'Pleiades' and 'Hyades'. Some stars which are very tightly packed in a small region appear as clusters. Clusters can be globular or open. Globular clusters have many hundreds of stars and open clusters have a few hundred stars. Pleiades and Hyades are open clusters.

There is a very interesting story about Pleiades. The seven stars in pleiades represent the seven wives of the seven sages in the constellation *Saptarishi*. The names of these stars are *Amba, Dula, Vitani, Abhrayanthi, Meghadanti, Varshayanti* and *Cupunika*. According to Greek mythology. Atlas, father of the 7 sisters was sent by God to support the Universe. To pacify the sad sisters, they were given place in the heaven. Through the telescope, you can see lots of stars. Amidst them, the 7 stars look like extremely bright diamonds. The Indian name for Pleiades is *'Krithika'*.

The other prominent stars are Castor and Polux of the Gemini Constellation. This is called *'Mithuna'* in Indian Astronomy. Gemini lies just above the bright

star Procion of Canis Minor and below the bright star Capella of Auriga. It is also popularly known as Twins. And of course, you can't miss the 'W' shaped constellation Cassiopia. This is going to guide you to the pole star.

The Stars of Spring

On spring nights, the Big Dipper lies high overhead. As you see, a line drawn through the pointer stars, in the pouring edge points to the Pole star. A line drawn in the opposite direction i.e. away from Polaris brings us to Leo, the Lion and its bright star, Regulus. Follow the arc of the Dipper and you come to Arctrus (a big red star) in Bootes. Continue the arc further south and you find spica, the bright star of Virgo.(fig. 31)

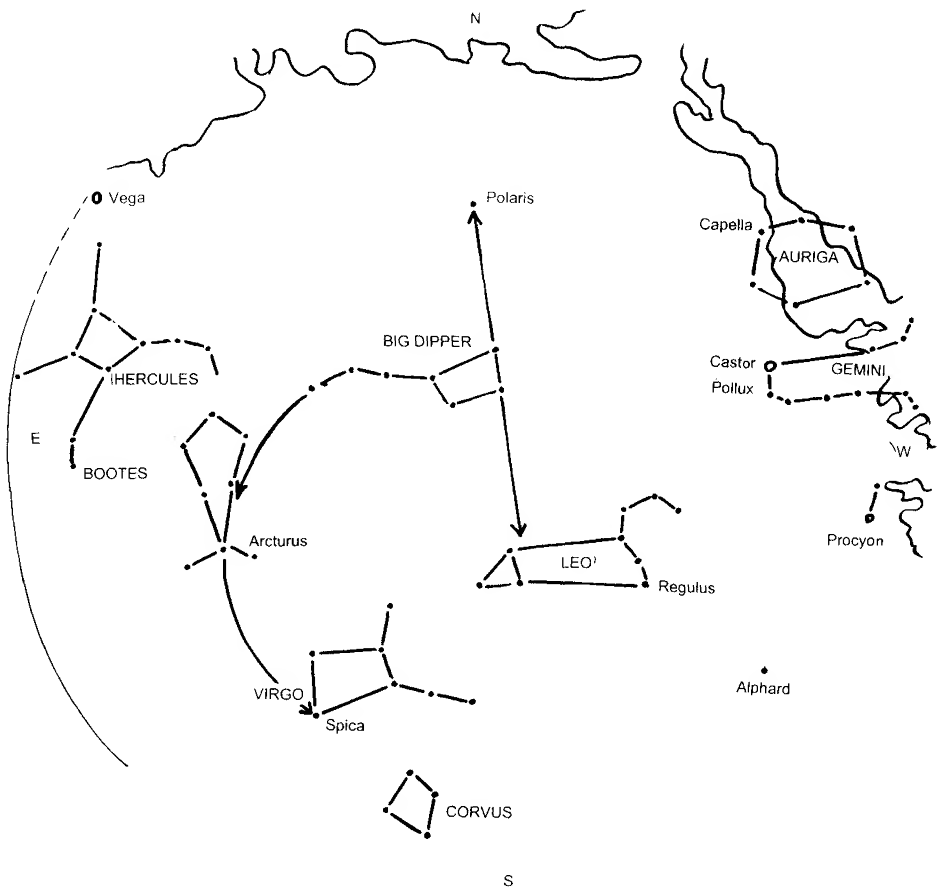


Fig. 31 The Stars of Spring

You can also see the constellation, Hercules. According to Greek mythology, Leo, the lion was killed by Hercules as the first of the twelve tasks assigned to him. As you move across the sky to the west, you can see the bright star, Capella of Auriga and bright stars Castor and Pollux of the Gemini constellation.

The Stars of Summer

In Summer, one can locate the famous summer triangle formed by Deneb, Altair and Vega. Deneb from the tail of Cygnus, the Swan, Vega from the Lyra constellation and the third vertex Altair belongs to the Aquilla constellation. You can refer to the detailed closeup chart of the summer triangle. The Indian name for Vega is *Abhijit*. According to *Mahabharata, Abhijit* was the younger son of *Rohini*. According to the Greek legend, Lyra is a celestial harp hung around the neck of an Eagle (fig.32)

Summer time is magic for amateur astronomers. Arching over our heads, like a great path of misty light, the Milky Way is the most remarkable naked eye feature in the sky. Enclosed by the summer triangle, is the constellation of Sagitta and an elusive irregular shaped cluster of stars (called M-71) can be seen. You might have to use a pair of binoculars to locate it. Another cluster called wild duck cluster (also called M-11) is seen to the southwest of Aquila (Refer to the figure of Summer triangle). (fig.33)

Other constellations that you can see are Scorpius which has a bright reddish star called Antares and to the east, teapot shaped Sagittarius can be seen. Although the pattern is supposed to represent an archer, the tea pot shape is what everyone looks for to locate the constellation.

As we move from Vega westwards, we can locate Bootes with the help of its bright star, Arctrus. Arctrus is an enormous red coloured star and its Indian name is *Swati*. The five stars of Bootes make a longish pentagon and at the tip of the long and tapering corner lies Arctrus.

Egyptians regarded Bootes as a Herdsman and according to another legend, Bootes was the inventor of the plough and Ursa Major as the plough itself. The most accepted is that Bootes was a hunter carrying two lively dogs in his left hand chasing the great bear.

As we move southwest from Arctrus, we can locate a bright star Spica of constellation Virgo. Spica means 'corn of wheat" but Arabians called it the 'Kennel'.

The Stars of Autumn

Autumn presents before us a remarkable part of Greek mythology. The 'W' pattern of stars 'Cassiopia' is seen overhead. Below Cassiopia, lies a flying horse called Pegaseus and close to Pegaseus lies the constellation of Andromeda, daughter of Cassiopia. Legend says that Andromeda was rescued by Perseus the hero. It is said that he had used the flying horse Pegaseus.

Aquila is seen just below the Milky Way. It is figured as flying eagle. Indian mythology says that *'Garuda'*, the eagle was held in bondage by the snakes, who wanted the nectar. *Garuda* fought with the Gods and *Indra*, got the pots containing the nectar and obtained freedom from bondage.

The body of the horse Pegaseus is formed by 4 stars and the figure joining the 4 stars is also called the square of Pegaseus. The three prominent stars of Pegaseus are Markab, Sheat and Algenib. The fourth corner of the square is Alpheratz, which belongs to Andromeda. If we extend the line joining this

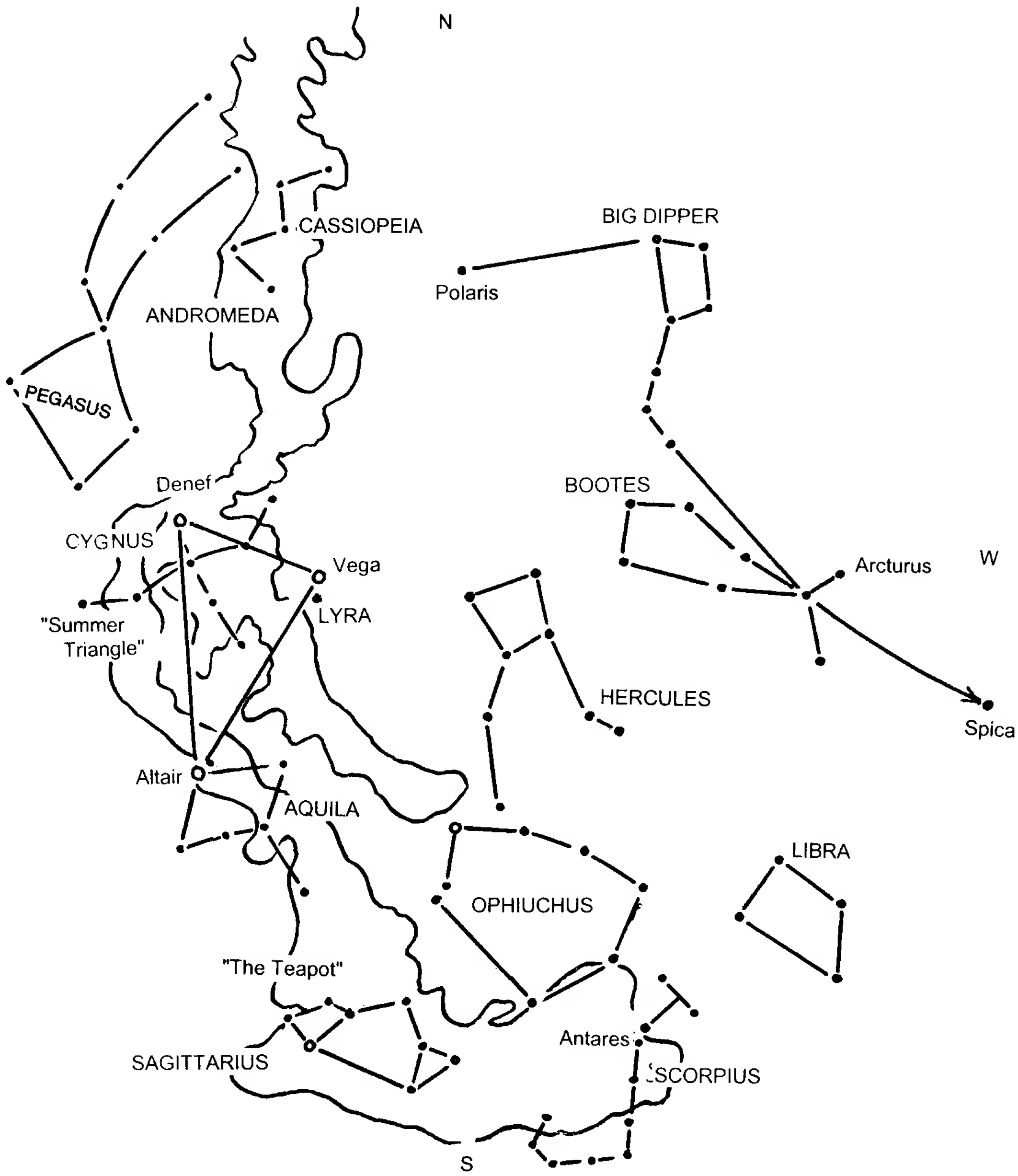


Fig. 32 The Stars of Summer

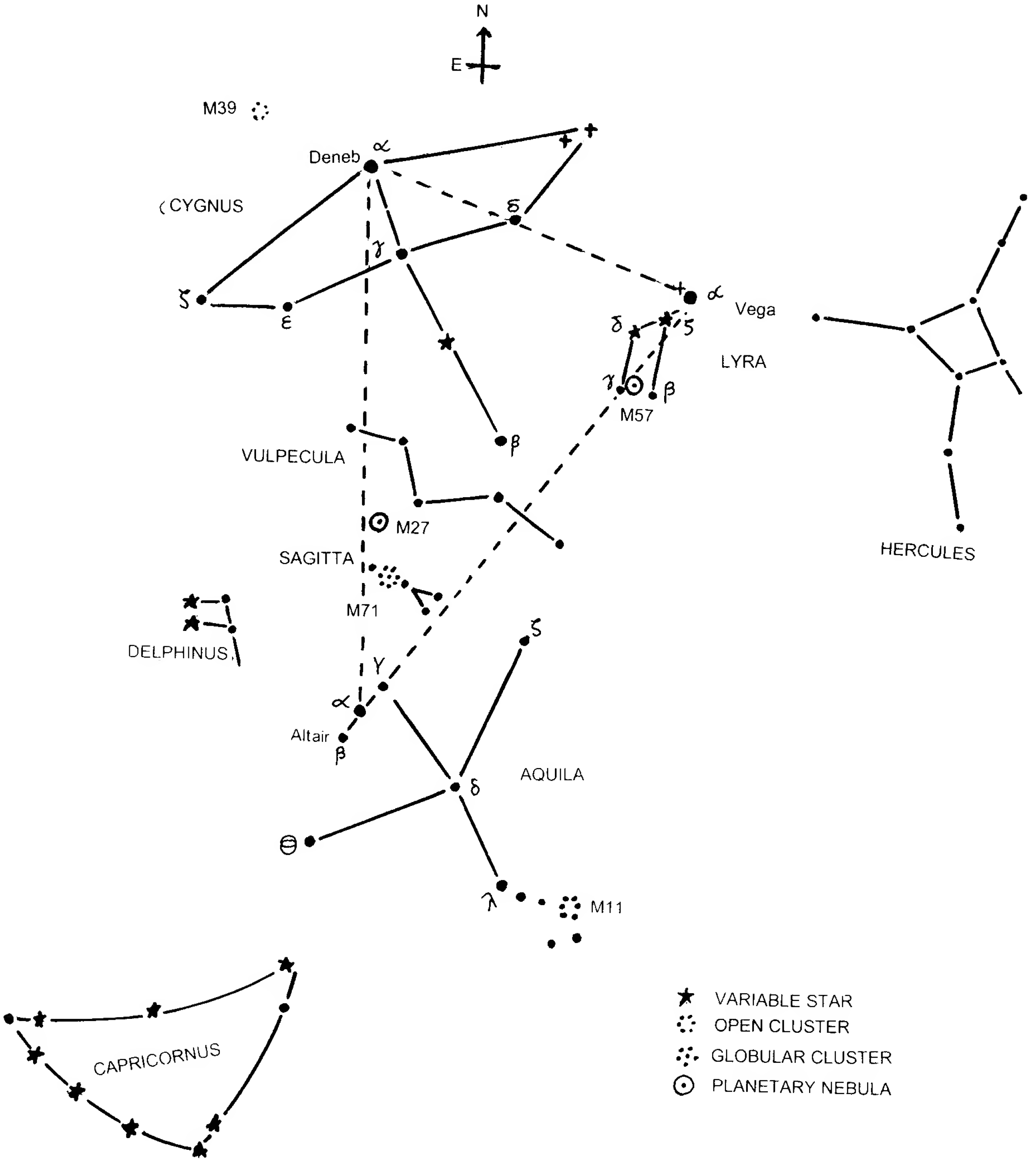


Fig. 33 The Summer Triangle

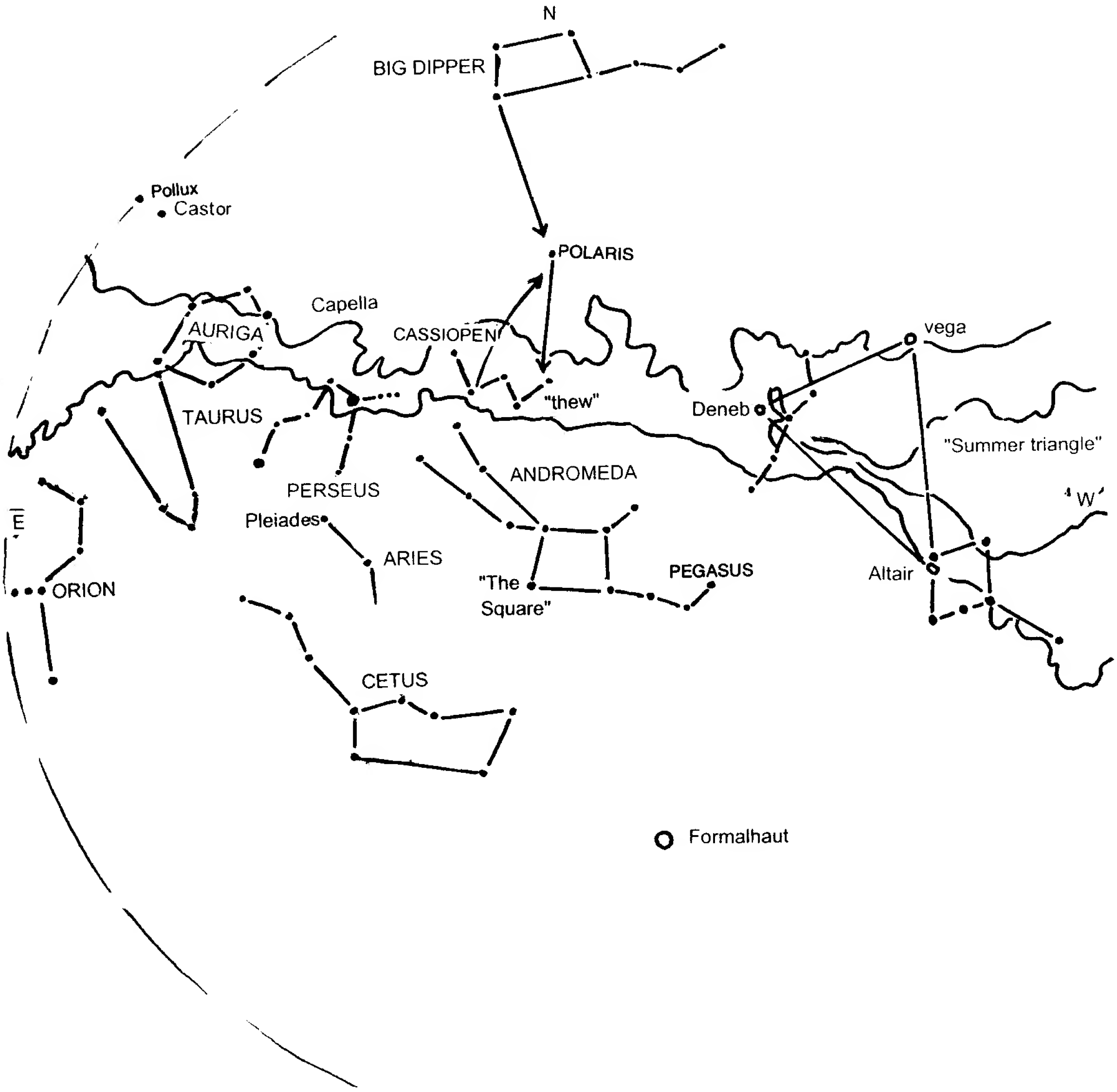


Fig. 34 The Stars of Autumn

star to Algenib by its own length (length=distance between Alpheratz and Algenib), we can reach the very important point of Vernal Equinox. Starting from the bright star of Perseus, when we move towards the square of Pegaseus, we come across the three bright stars of Andromeda. They are Almach, Mirach and finally Alpheratz, the fourth corner of the square.

The Indian version of the legend is even more interesting. Once upon a time, there was a king called *Vrishaparva*, son of sage *Kashyapa*. He had a daughter named *Sarmishta*. The other charachters in the story are *Devayani*, daughter of sage *Shukracharya* and prince *Yayati*. *Sarmishta* and *Devyani* were

great friends. But once, when they had a fight, *Sarmishta* pushed *Devayani* into a well. As in all the other stories, a prince named *Yayati* rescued and married her and they lived happily everafter.

As we move eastwards from Perseus, we can see Taurus and as we move further east, we come across the Orion constellation. As we move down south from Persueus, Aries can be seen.

●●●

CHAPTER 4
Let us Now Explore the Night Sky

Though there are million of stars, we can see only around 3000 stars with the unaided eye. The stars can be identified by their brightness and from the constellation to which they belong. Brightness is denoted by Greek alphabets. The brightest star of a constellation is denoted by α and the others by ß,Y,δ etc. according to the decreasing order of their brightness. Pole star is α in Ursa minor.

The ten brightest stars are **Sirius** from Canis Major, **Canopus** from Carina, **Centauri** from Centauris, **Arctrus** from Bootes, **Vega** from Lyra, **Capella** from Auriga, **Rigel** from Orion, **Procyon** from Canis Minor, **Betelgeuse** from Orion and **Archernar** from Eridanus in the decreasing order of their brightness. This is the brightness of stars as seen from the earth. This is called apparent magnitude of the star.

Our Sun is the brightest star seen from the earth as it is closest to us. There are many stars brighter than the Sun, but due to their large distance from the Earth, they do not appear as bright as the Sun.

Now some simple tips for star observation

1. Choose a moonless night or moonless part of the night.
2. Select a place far away from the bright city lights.
3. Select a place where the view is not obstructed by tall buildings, tall trees etc.
4. A good star map either monthly or season wise star map and a torch covered with red cellophane paper.
5. Get oriented by locating the pole star with the help of Ursa Major or Cassiopia.

Try to identify one or more of the following 'land marks' in the sky. The spring triangle formed by Regulus, Arctrus, and Spica, the summer triangle formed by Vega, Deneb and Altair, the square of Pegaseus or the winter polygon formed by Capella, Aldebaran, Rigel, Sirius, Procyon, Pollux and Castor. While observing the southern sky,use the southern cross.

For observations, use a suitable star chart provided in this book or star charts obtained from planetaria. You can also use the monthly star chart brougth out by newspapers and magazines. A planetarium in your city can be the best place to start knowning more about stars and constellations. The night sky of any place at any time on any day and any part of the year can be projected in the sky theatre of the planetarium.

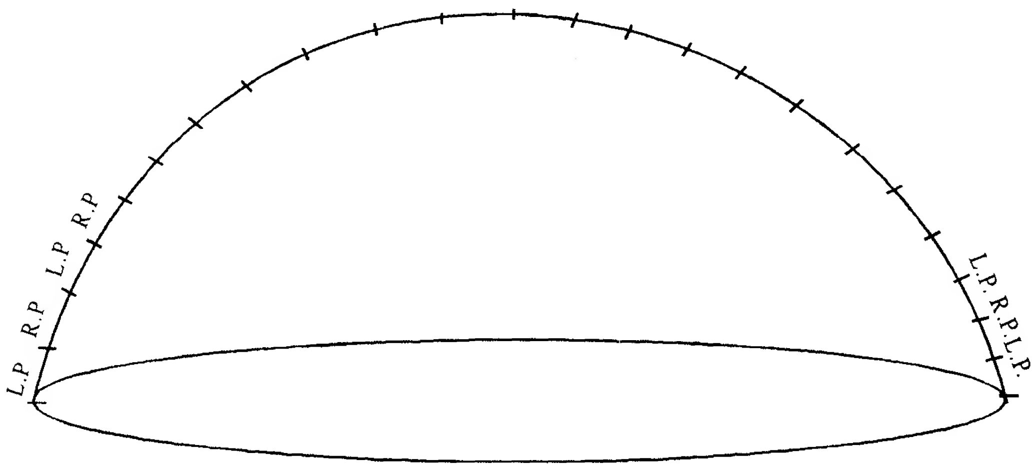
Estimation of Distances in the Sky

It is very important for beginners to estimate the distance between stars as seen from earth. When you are looking at a star and move to look at another one, you are changing the direction of line of sight. The angle between the

lines of sight is called angular distance between the stars. The angular distance can be estimated by using your hands. But, first you have to calibrate it. Let us see, how it can be done. Ref. to (fig. 35)

Follow the steps as given:

1. Choose a place where you can see the horizon circle clearly.
2. Stretch your left hand out, with the palm.
3. similarly, use the right hand and continue this process till you move from horizon to horizon via zenith (as shown in the figure). Count the number of times you used your hands. Let it be = n



HORIZON CIRCLE

Fig. 35

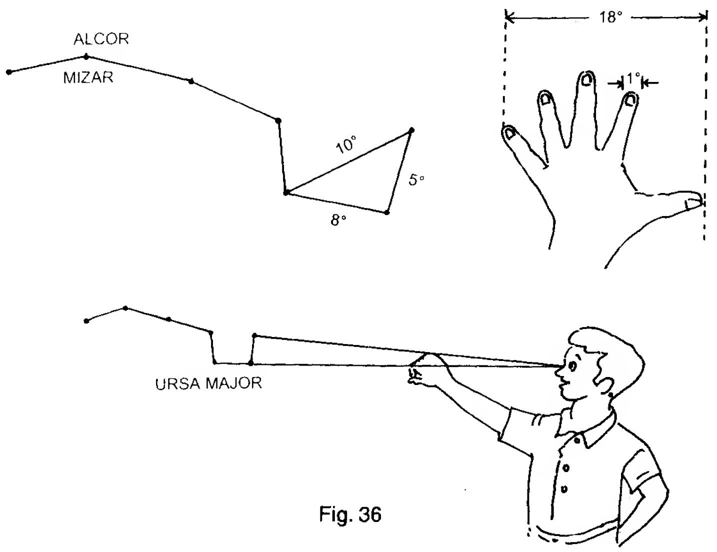


Fig. 36

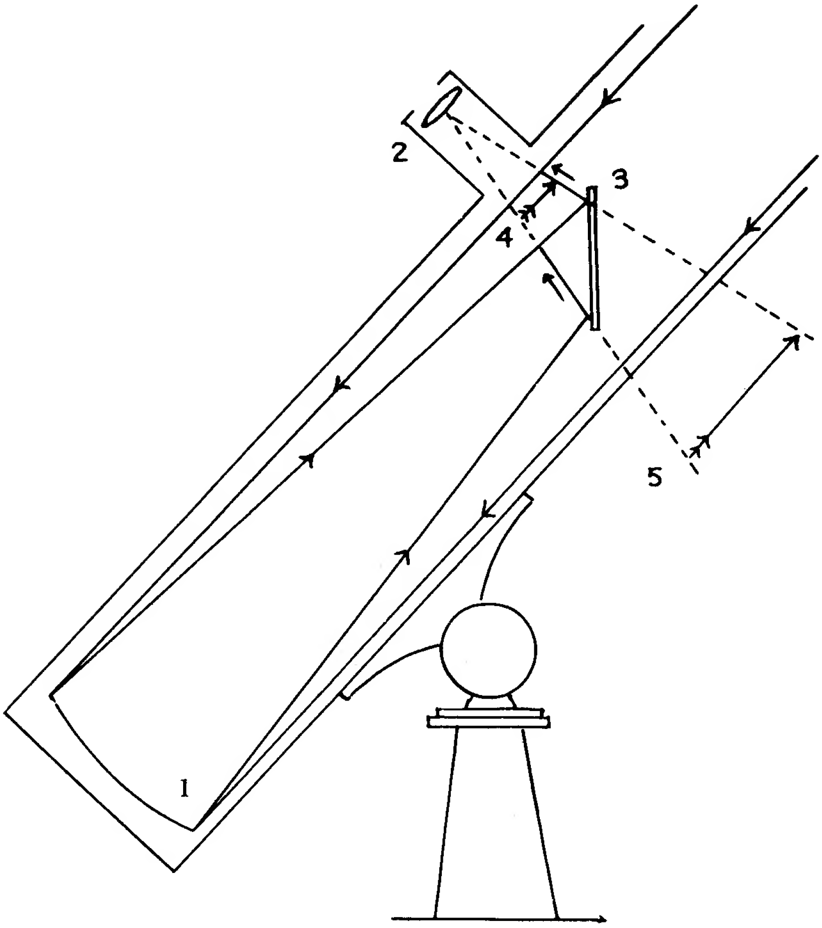


Fig. 37 Reflector Telescope

1. Concave Mirror (Objective)
2. Eye Piece
3. Plane Mirror
4. First Image
5. Magnified Image

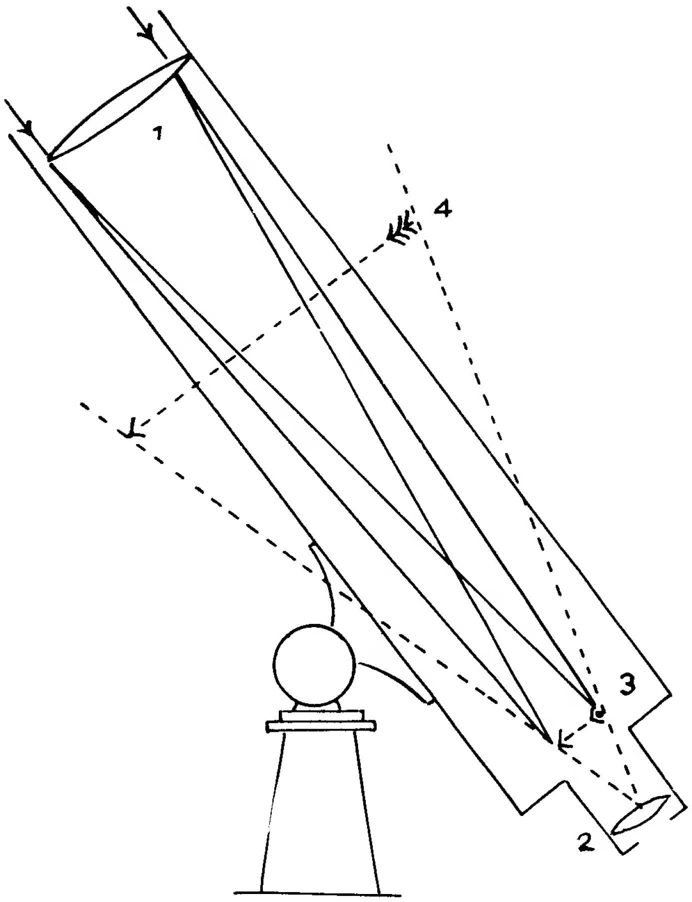


Fig. 38 Refractor Telescope

1. Convex Lens (objective)
2. Eye Piece
3. First Image
4. Magnified Image

Angle made by your stretched palm=180°/n. It is approximately 18⁰.

You can also use your thumb or fist to measure smaller angles.

Width of a finger is 1° and the fist is 5°.

e.g. Diameter of the moon = ½°

Distance between the pointer stars of Ursa major = 5°

The sides of triangle formed by the pointer stars and the third star are 5° 8° and10° respectively.

How do we see stars ?

We see a star by the light it sends out. The light from the star falls on the entire earth, but our eyes use only a small fraction which enters the pupil. So we can see only bright stars.

If we want to observe fainter objects and see them in great detail, we must use a telescope. A pair of binoculars could also be used. The binoculars should have stable support like tripod.

How does a telescope help us?

A telescope has a lens or a parabolic mirror which collects light from a distant object and focusses it. This is called the objective. A second lens called eye piece is used to make most of the light collected by the objective to reach our eye. The image formed by a telescope is inverted.

The size of telescope is specified by the diameter of the objective. The diameter is called the aperture of the telescope. The light collected by the telescope depends on the size of the aperture. If the aperture is doubled, 4 times fainter stars can be seen. A telescope's optical performance is defined by:

i. Aperture size
ii. Resolving power
iii. Magnifying power and
iv. Field of view

The ability to distinguish 2 close features is called resolving power. The resolving power also depends on the aperture. The magnifying power of a telescope is given by the ratio of the focal length of the objective to the focal length of the eye piece. Magnifying power can be increased by using an eye piece of a smaller focal length. Magnifying power = f_o/f_e.

The ratio of the aperture to the focal length of the objective is called the f-ratio of the telescope. The f-ratio of a telescope defines the field of view of the telescope. If the f-ratio is small, the telescope can see a larger extent of the sky.

$$\text{f-ratio} = \text{Aperture}/f_0$$

If the objective is a convex lens, it is called a refractor telescope (fig.37) while the one that has a mirror as objective, is called a reflector telescope (fig.38)

When you start using the telescope, turn the telescope towards the moon, choose the night when it is half or three fourths. You will see hills and craters

on the moon.

To locate stars, and other heavenly bodies, you should know the direction and approximate position of the star. The accessories needed are a star chart and a torch covered with red cellophane paper. Before observing, mark the predicted position of the star on the star map and turn the telescope towards the predicted position in the sky.

For observations of the Sun, place a white paper or screen in front of the eye piece to get the image of the Sun. You can observe Sun spots.

***Warning :** Never look at the Sun directly or through a telescope as the Sun will harm your eyes permanently.*

●●●

CHAPTER 5
Stars, Constellations and Festivals

Many festivals in India are timed according to the position of the Sun and the moon amongst the constellaitons in the sky. *Deepavali* is celabrated on the new moon day of the month of *Saura Kartika* (between 15th October and 15th November) when the new moon is near *chaitra nakshatra* and *Eid-ul-zuha* is celebrated on the tenth day after new moon in the *Zulhijja* month. *Kartik Poornima* is celebrated on the full moon day following (Delphinus) *Deepavali*. When the full moon is near *Dharmishta nakshtra, Raksha Bandhan* is celebrated. Quite often, celebration of festivals is associated with seasonal activities. But the timing of some of these festivals is effected by the precession of earth.

Makara Sankranti is celebrated when the Sun enters the constellation Capricornus or *makara rasi*. When the Sun entered Capricornus, it was winter solistice on earth i.e. after this day, the Sun appears to start moving from Tropic of Capricorn towards equator. This is called *Uthirayan*. Now winter solistice falls on December 22nd but *Makara Sankranti* is celebrated on January 14th, 24 days after Vernal equinox. This is due to precession.

Most of the festivals come once a year and are controlled by the rhythms of moon going round the earth and the system of earth and moon going around the Sun. But Kumbh Mela, the largest festival of India comes only once in twelve years. How is the particular day found?

The legend says that Devas and Asuras churned the ocean in search of 'Amrit'. Finally when *Amrit* came out of the ocean. Indra's son Jayanta flew away with the *Amrit* to prevent the *Asuras* from drinking it. For 12 long years,

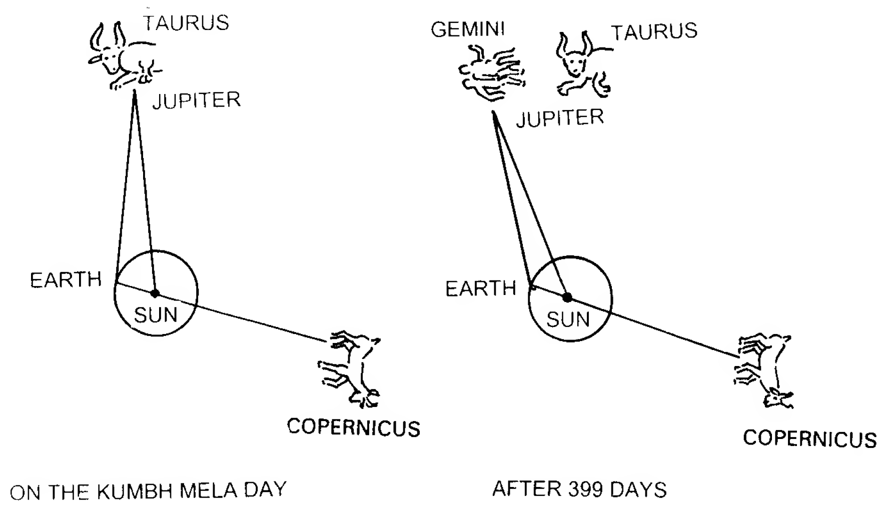


Fig. 39

he went from place to place with the *Asuras* chasing him. He flew down to rest in Allahabad, Haridwar, Ujjain and Nasik, spilling drops of *Amrit* in the four rivers Ganga, Yamuna, Shipra and Godavari and thus made them sacred. While Jayanta rested, the Sun, moon and Jupiter kept watch over the *'Amrit Kalash'*. Let us compare it with the actual astronomical condition.

Kumbh mela is celebrated when the Sun and moon are in *Makara rasi* and Jupiter is seen in the backdrop of *Kruthika* cluster in Taurus constellation. Once in 399 days, the same arrangement i.e. the same triangle is formed. But the background of Jupiter changes i.e. to Gemini constellation. To come back to the original position with Jupiter in Taurus and Sun and moon in *Makara rasi*, it takes 12 years.

Moon, Tithis and Nakshtras

The moon goes round the earth and the earth-moon system goes round the Sun. Full moon occurs when the moon and the Sun are in the opposite directions in the sky as seen from earth. On this day moon rises when the Sun sets and sets as the Sun rises. After the full moon, each night, the moon rises later than the previous night and its shape (the lit face as seen from earth) also changes. Nearly two weeks after the full moon, the moon and Sun are in the same direction of the sky and the lit side of the moon is not visible from the earth. On this day i.e. *Amavasya* day (called the new moon day) moon and Sun rise together. Exactly 29.53 days after the full moon, it comes back to the direction opposite to the Sun in the sky and then the moon is again full (fig.40).

More than 3000 years ago, the rhythmic change in the shape of the moon formed the basis of our calendar. The phase of the moon is called thithi. The first 15 tithis belong to the waxing half called the *Shukla Paksha* and the next 15 tithis belong to the waning half called the *Krishna Paksha*.

The Lunar Time Table

Tithi	*Phase*	*Rising time*	*Setting Time*
Amavasya	*New*	*Sunrise*	*Sunset*
S.Chaturthi	*Waxing*	*3 hrs after Sunrise*	*3 hrs. after Sunset*
S. Ashtami	*Waxing*	*Noon*	*Midnight*
Ekadasi	*Waxing*	*3 hrs after noon*	*3 hrs. before Sunrise*
Poornima	*Full*	*Sunset*	*Sunrise*
K. Chaturthi	*Waning*	*3 hrs. after Sunset*	*3 hrs. after Sunrise*
K. Ashtami	*Waning*	*Midnight*	*Noon*
K. Ekadasi	*Waning*	*3 hrs. before Sunrise*	*3 hrs. after noon*
Amavasya	*New*	*Sunrise*	*Sunset*

Let us see how many such cycles should be completed for the full moon to be seen in the backdrop of the same star.

In the month of November, on the full moon, as seen from earth, Sun is seen in the backdrop of Scorpion Constellation and moon is seen in the backdrop of Krithika nakshtra.

On the next full moon day, in the month of December, Sun is seen in the backdrop of Sagittarius constellation and the full moon is seen in the backdrop of Punarvasu nakshatra.

It takes thirteen such cycles for the full moon to be seen in the backdrop of the same nakshatra (fig.40).

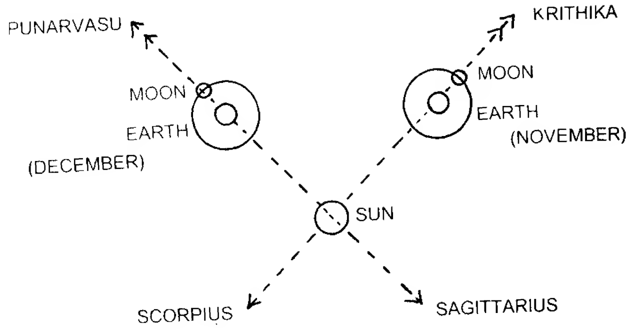


Fig. 40

● ● ●

CHAPTER 6
Astronomy in India

Astronomy is called the foremost auxiliary of the Veda. Rig Veda says "Just like the combs of peacocks and crest jewels of serpents, so does astronomy stands at the head of the auxiliaries of the Veda".

Tremendous work has been done in this field since Vedic times. Later, starting from 5th Century A.D., *Aryabhatta I, Prabhakara, Bhaskara I, Brahma Gupta, Vateswara, Aryabhatha II, Someswara, Sutananda, Bhaskara II, Amaraja, Parameswara, Chakradana, Jyeshthadeva, Viswanatha, Nithyananda, Swami Jayasimha, Jagnnatha Samrat* and *Sankaravaraman* were some of the great Indian astronomers. In this historical period many works of Indian astronomical literature were produced. They can be grouped under the *Siddhanthas, Karanas* and *Kosthakas*. The astronomical instruments developed are called yantras. I would like to show you the calendar of 1182 B.C. which shows the relative

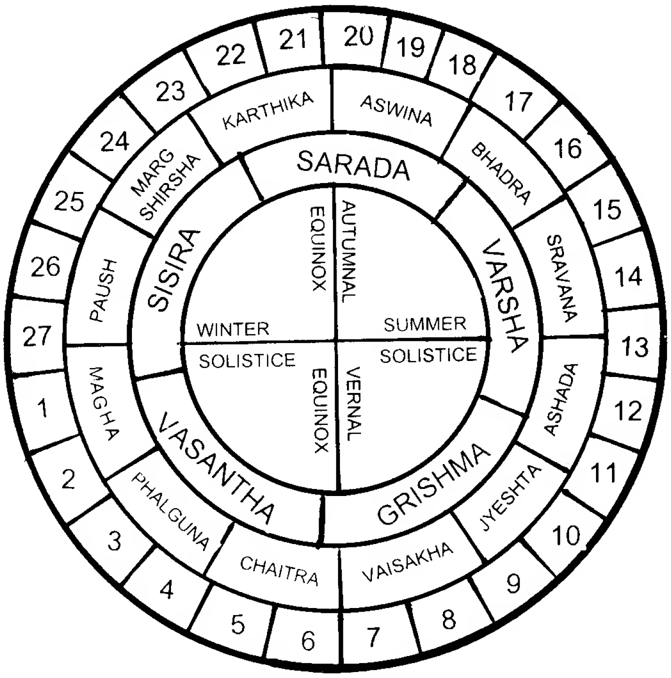


Fig. 41 The Lunar Calendar

position of lunar mansions, months and seasons (fig.41)

According to this calendar, the year was divided into five seasons viz. *Grishma, Vasanta, Sisira, Sarada* and *Varsha*. The year was divided into 12 months (as shown in the figure) and the lunar belt of 27 nakshtras.

Yantras of Jantar Mantar

Jantar Mantar or the Yantra mandir—the temple of instruments. Talking of Yantras, what comes to one's mind are the observatories or *Jantar Mantar* built by Maharaja Sawai Jai Singh II.

Year 1719 A.D., Place : Delhi, Location : Red fort - A noisy session about the auspicious time for the emperor Mohammad Shah to embark upon a big expedition. The *maulvis* and *pandits* did not have astronomical laboratories to verify the calculations and hence the confusion and debate. The spectator was Maharaj Sawai Jai singh II. He decided to construct huge stone astronomical observations to educate people. By 1724 A.D., the first observatory at Delhi was completed. The maharaja himself carried out experiments and observations for nearly seven years at this observatory. The next one was constructed at Jaipur in 1728 A.D. and the others at Ujjain, Varanasi and Mathura. All the yantras were made of red sand stone, marble and iron.

Sawai Jai Singh wanted to promote the scientific approach to astronomy and astrology. To acquaint people with the scientific aspect of the Sun, moon, stars and the various astronomical phenomena, he designed the various yantras. Let us learn how to use some of these yantras. You can also make your own *Dhoop-Gari* (Sundial) and star clock.

The Horizontal Sundial

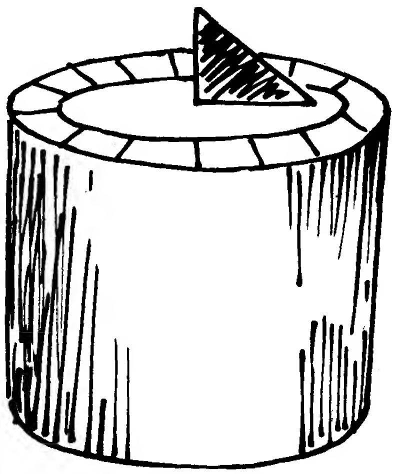


Fig. 42 The Horizontal Sun - Dial - 'Dhoop Ghari '

This *ghari* has a neatly graduated Circular scale and a triangular gnomon fixed at its centre, the base angle of the triangle being equal to the latitude of the place. The shadow of the gnomon indicates the solar hours in'Ghatikas'. Do you want to make your own *Dhoop-Ghari*? Then go on and follow the instructions (refer to project VI) make one and compare with the *Dhoop-Ghari* of *Jantar Mantar* (fig. 42)

As the base angle of the gnomon is equal to the latitude of the place, its slanting edge is always parallel to the earth's axis. During the day, as the Sun moves across the sky, the shadow of this slanting edge is cast on the circular scale.Raja Jai Singh made another type of Sundial called the Samrat yantra.

Lagu Samrat Yantra : It is also called the small equatorial Sundial. A right triangle with base angle equal to the local latitude is the gnomon. The two quadrants on both sides of the gnomon, are inclined at an angle such that the arc is parallel to the earth's equator. As the shadow moves across equal arcs on the quadrant, it measures equal intervals of time (fig.43)

The Pole Star Instrument: The *Dhruv darshak yantra* is a simple instrument

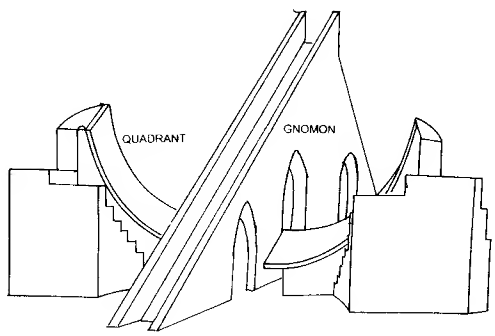


Fig. 43 Small Equitorial Sundial

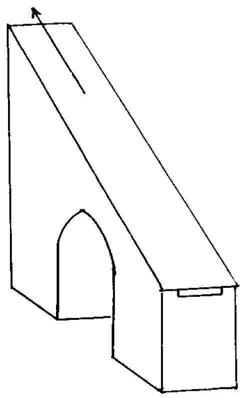


Fig. 44 Pole Star Instrument

which indicates the celestial north and helps the observer locate the pole star. The observer has to look towards the sky along the slope of the instrument to see the *Dhruv tara*. The base angle is equal to the latitude of the place (fig 44).

The Ecliptic instrument : This *Yantra called Kantivritta Yantra* is one of the few metal instruments of the Jaipur observatory. One of its two metal frames rests and rotates on a masonary base which is inclined to the plane of equator by 23and1/2 degrees. The upper metal frame lies and rotates in the plane of ecliptic i.e. it is inclined at an angle of 23and1/2 degrees. Thus the metal frames and their masonry base put together make an angle of 47 degrees.

The stone circle is graduated into 24 hours and further sub divided into minutes and seconds of arc. The metal frame is graduated in 360 degrees along with 12 zodiacal signs.

There is a separate metal tube, which is fitted in the hole at the centre of the ecliptic frame. The stars and planets are observed through this tube. This instrument can be used to find the distance of stars and planets from the equinox and distance from the ecliptic (fig. 45)

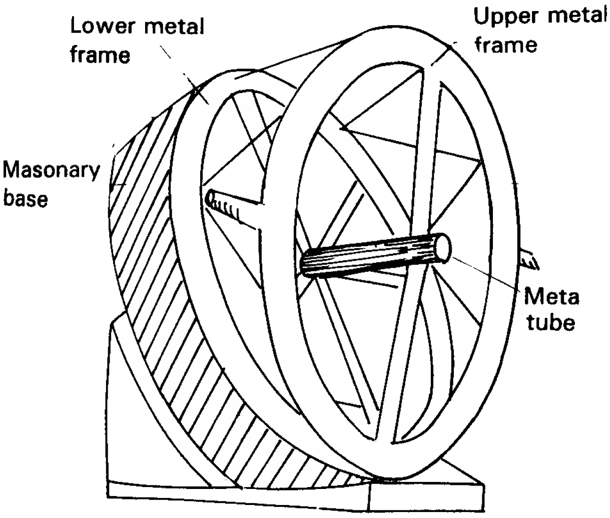


Fig. 45 The Ecliptic Instrument

The Weather Forecast Belvedere (Chatri)

The equatorial Sun dial (*Samrat Yantra*) is crowned by a beautiful belvedere

(*Chatri*), which is still used for forecasting the coming of monsoon, storms, droughts and famines. Such weather forecasts are based on the direction of the wind which is observed on top of the *Samrat yantra* on *Ashadh Purnima* or *Guru Purnima*, which is the full moon day in the Hindu month of *Ashadh* (June-July).

A thin muslin flag is hoisted to find the exact direction of wind and weather is forecast accordingly. An "Easterly" indicates good rains and crops, whereas a southern wind means a bad monsoon and probable famine. Heavy rains and floods are caused by the "Westerly" and the northern breeze also brings in plenty of rains and abundant crops.

The Zodiacal Instruments

Known as 'Rashi Yantras' or the 'Rashivalaya', it is a group of 12 instruments representing the 12 zodiac signs.

They look like smaller versions of the equatorial Sun dial, but are different in some respects. The gnomons of the zodiac instruments indicate the pole of the Ecliptic at the time of observation. The quadrants of the zodiac lie in the plane of the ecliptic (fig. 46).

The gnomons of the *Rashi Yantras* face different directions according to the different situations of each zodiac sign from the pole of the ecliptic.

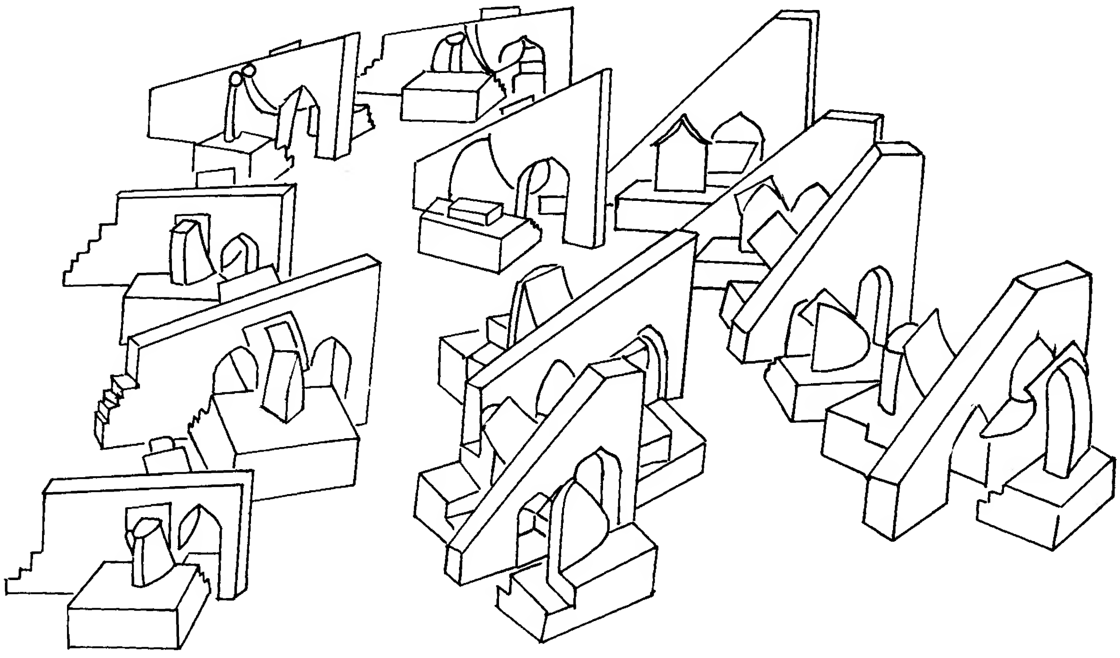


Fig. 46 The Picturesque Complex of Twelve Zodiac Instruments

These instruments were used for direct observation of the latitudes and longitudes of the Sun and planets. The astronomical data thus collected were used to compile the astronomical tables, ephemeris and almanacs.

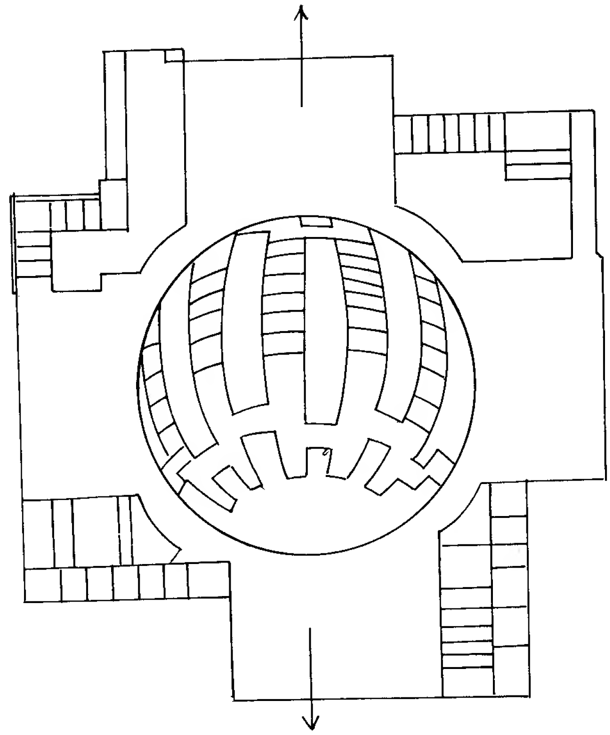


Fig. 47. One of the Complimentary Parts of the Armillary Sphere Instrument

The Armillary Sphere Instrument :

It is known as *Jai Prakash Yantra* -meaning the "light of Jai". The armillary sphere consists of two hemispherical bowls Sunk in the ground. It represents the celestial sphere turned upside down. The rim of the bowls represent the horizon which is graduated in 360 degrees. The central point at the bottom represents the Zenith, through which the local meridian circle is drawn North-South. Another prominent line is the East-West running celestial equator. Meridian parallels (Azimuth Circles), horizontal/parallels (altitude circles) and twelve zodiacal circles are drawn on the surface of the hemisphere (fig.47).

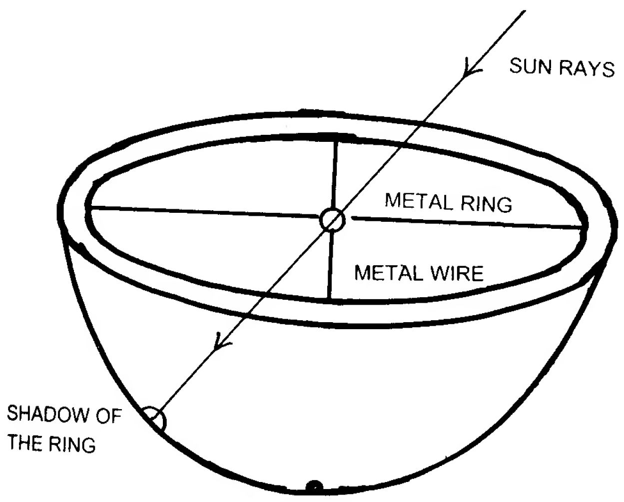


Fig. 48. The Hemispherical Bowl Instrument

A cross section of metal wires holding a metal ring at the centre is fixed over the four directions over the *yantra* in such a way that the metal ring is exactly above the zenith (fig 48).

The shadow of the ring (cast by the Sun) is cast on the graduated surface below. The distance between the centre of the shadow spot and the lines of horizon, local meridian, celestial equator and Zenith would indicate local time, Altitude, Azimuth, Zenith distance and declination of the Sun.

The Composite Instrument - Mishra Yantra

It is found at the Jantar Mantar at Delhi and consists of five astronomical devices. The meridian wall instrument, small equatorial Sundial, zodiac instrument, amplitude instrument and the fixed instrument. The fixed instrument (*Niyot Chakra Yantra*) is a very interesting heart shaped instrument. There are four semicircles inclined to the plane of Delhi meridian by four different angles corresponding to the differences between the longitudes of Greenwich (England), Zurich (Switzerland), Notkey (Japan), Seritchew (an island in the Pacific) and that of Delhi (fig.49). The picture of this composite yantra was used as the logo for Asian games held in Delhi in 1982.

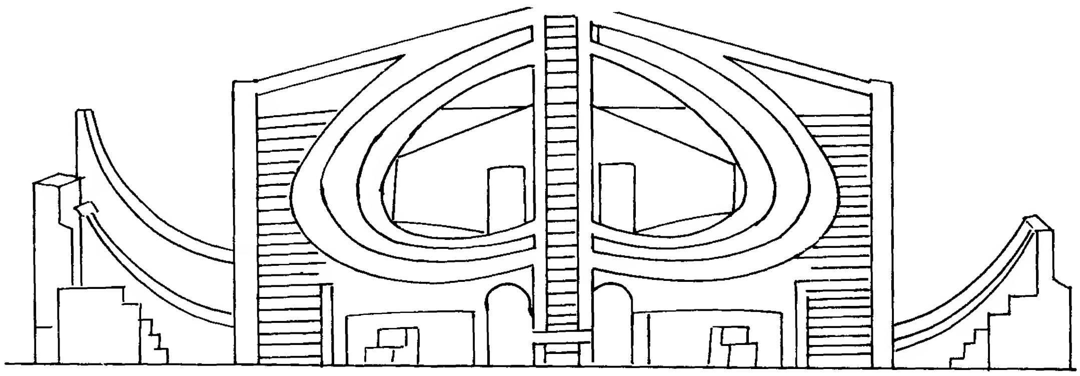


Fig. 49 The Composite Instrument - Mishra Yantra

There are many more yantras in the Jantar Mantar keeping Sun, moon and the stars as time keepers, with the pole star and vernal equinox where ecliptic and celestial equator are the fixed reference points.

Even today the star catalogues and methods of calculations devised by Raja Jai Singh are used in Rajasthan to complete the 'panchang'. Jai Singh's aim to prepare an accurate catalogue would have been achieved by just one observatory. But he wanted to make comparative observations of checking and verifying the observations made at one place with those at the others. He gave a new dimension to the pursuit of science in our country. His objective method made him the first modern Indian scientist.

●●●

CHAPTER 7
Hello Stars ! How Are You?

When Sunlight passes through a prism, it is split into seven colours; violet, indigo, blue, green, yellow, orange and red. We see these colours in the rainbow too! Sun is a star and when light from a star pass through a prism, it is also split into its constituent colours. It is called the Spectrum.

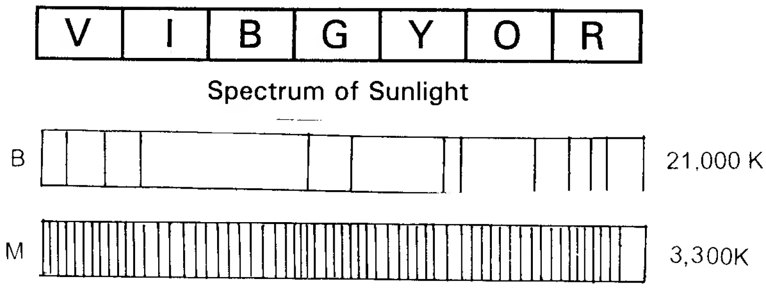


Fig. 50 Stellar Spectra of Stars Belonging to B and M Classes Showing the Dark Absorption Lines

All stars are mainly made up of Hydrogen, some Helium and other heavier elements. Spectra of stars have some dark lines on them. They are called absorption lines and these are actually the signatures of the components of a star. According to their spectra, stars are classified and denoted by letter O, B, A, F, G, K and M. The differences are mainly due to the difference in surface temperatures of the stars.

Spectral Class	Star	Temperature (°K)
O	Lacertae	25,000 and above
B	Rigel in Orion	11,000-25,000
A	Sirium in Canis Major	7,500-11,000
F	Prixyon in Canis Minor	6,000-7,500
G	Sun & Capella in Auriga	5,000-6,000
K	Arctrus in Bootes	3,500-5,000
M	Betelgeuse in Orion	3,500 and less

The surface temperature, the rate of emission of light energy from the star and its distance from the earth determine the absolute magnitude of a star. Hertsprung Russel diagram is the graph of absolute magnitude of stars plotted against their spectral classes. The brightest in the sky Sirius A, Procyon, Sun and Proxima centauri (nearest star to us if you do not count our Sun) etc. lie on the main sequence area, giants like Arctrus and super giants like Betelgeuse lie on the right hand top of the graph and white dwarfs like Sirius B lie to the left hand bottom of the graph. Sirius B is thousand times fainter than Sirius A (fig51).

Distance of Stars

A long time ago, Aristotle and Tycho Brahe thought that the earth was stationary because the stars did not appear to shift as seen from earth. This is because of the great distances of the stars from earth and not because of earth being stationary. How do we measure such large distances? The method used is Triangulation. It is based on the principle of parallax measurements.

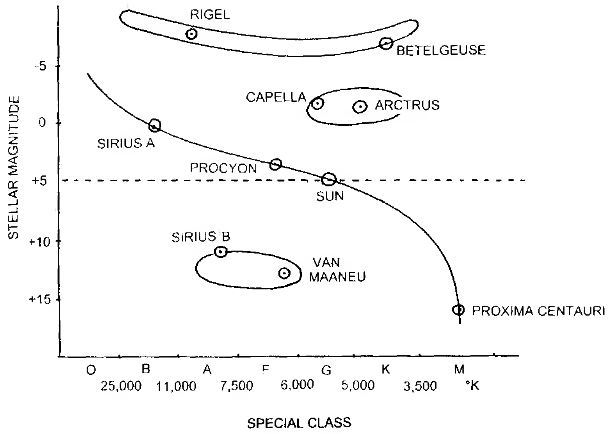
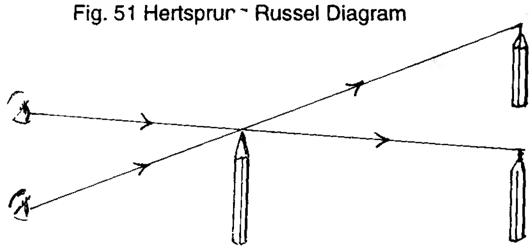


Fig. 51 Hertsprur - Russel Diagram

If you hold a pencil in front of you, close your left eye and observe it with your right eye and then close the right eye and see with the left eye, the pencil would appear to jump from left to right. This is called Parallax (fig52).



PARALLAX
Fig. 52

If you want to find the distance of a star (say Sirius), then observe it against the backdrop of a distant star in a particular day of say the month of March. Repeat the observation from the same place in the month of June (Ref. fig53).

PQ is called the base line which is equal to the radius of earth's orbit round the Sun. α and β are the angles between the backdrop (reference) stars and the direction of the star (Sirius), whose distance is to be found.

Stellar parallax $\theta = \alpha + \beta$

D is the distance of the star from the earth.

$D = PQ/\theta$ (α, β and θ are measured in radians)

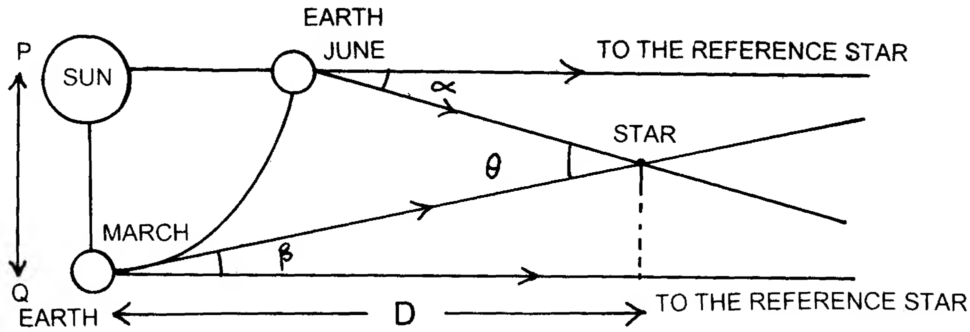


Fig. 53

A star with a parallax of 1 second of arc is at a distance of 2,06,265 astronomical units and this is called 1 parsec.

1 Astronomical unit =Radius of the earth's orbit round the Sun = Average distance of the earth from the Sun.

1 parsec = 3.086×10^{14} K.M.

All astronomical observations require patience. It is only after many evenings of practical observations that you can locate and identify stars, constellations and other heavenly bodies like star clusters, nebulae etc. and also observe details on the Moon's surface, phases of Venus, belts of Jupiter, Saturn's rings etc. The observation of Sun spots and eclipses is also very interesting. If you wish to be an amateur astronomer, you should use a good pair of binoculars or a telescope for your observations. You can make your own telescope for observations. Beautiful and interesting views of space are revealed every day and every hour.

"To follow knowledge like a sinking star,
Beyond the utmost bound of human thought......
"To strive, to seek, to find and not to yield".

--Tennyson

●●●

Model 1

PROJECTS I to V

Five in One

This model can be used

I. To find the True North,

II. To find the latitude of a place,

III. To find the time using it as a Sundial and

IV. To prove that the Earth's axis is tilted at an angle to the vertical.

V. To study the length of the shortest shadow on different days of the year.

Materials Required :

i. 30 cms x 30 cms. thick cardboard

ii. White paper of the same size

iii. Used ball point refill

iv. Instrument box.

v. Scissors and glue.

Process : Cover the cardboard with the white paper. Mark its centre and make a small hole at that point. Fix the ball point refill at the point. See to it that it is fixed absolutely vertical.

PROJECT - I

To find the True North

Determination of True North is the important step in many astronomical experiment and observations.

Steps involved in the experiment are:

Step 1 : Place the cardboard on a level surface in a place which would receive Sunlight throughout the day. Mark the outline of the cardboard on the ground.

Step 2 : Fix the ball point refill at the centre of the card board, taking care that it is exactly vertical.

Step 3 : At around 11 AM draw the line of shadow and measure it. R emove the ball point refill and with the centre point of the cardboard as centre and the length of the shadow as radius, draw a circle with the help of compass.

Step 4 : Replace the refill again in its original place. Go on marking the tips ofthe shadows at intervals of 15 minutes. After 12 O'clock, at a certain time, the tip of the shadow will touch the circle. Mark the point and join it to the centre.

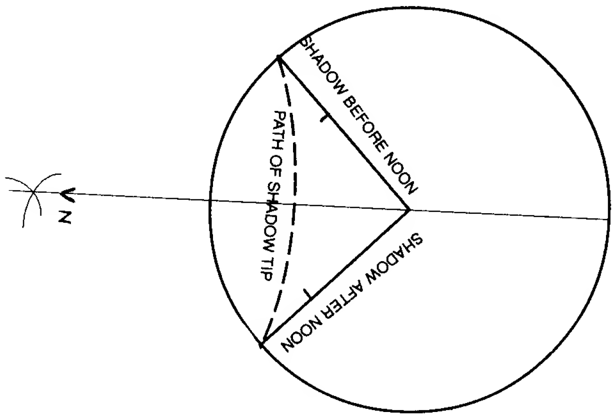


Fig. 54

Step 5 : Now remove the refill and bisect the angle with the help of compass. This bisector gives the direction of True North (fig. 54)

Extension Project :

1. Using the True North direction from the experiment, try to identify the pole star at night.
2. By conducting the experiment on 4 or 5 consecutive days, find out whether the length of the shadow at a particular time(say 11 A.M.) changes from day to day.

Precautions:

i. The position of the cardboard should not be changed.

ii. The refill should be absolutely vertical.

PROJECT - II
To find the latitude of the place

The model used in the previous experiment can be used for this project.

Proces : Steps involved are:

Step 1: From the previous experiment, measure the length of the part of the refill which is above the cardboard.

Step 2: Divide the length of the shortest shadow by the length of the refill. This gives the Tan of the angle made by the Sun's rays with the refill. Let this angle be α. Find out α from the Tan tables (table A)

Step 3: From the table of latitudes, find the latitude at which the Sun is overhead on that particular day. Let that be ß (table B)

For places in the Northern hemisphere :

During summer in the Northern hemisphere, Latitude = α + ß

During winter in the Northern hemisphere, latitude = α - ß

Let us take an example (say the experiment is conducted on 5th March in Delhi)

Length of the refill = 14 cms.

Length of the shortest shadow = 9.7 cms

$\therefore$ Tan α = 9.7/14 =0.69285

From the Tangent table, corresponding value of α = 34°43'.

Table B
Latitudes at which Sun is overhead on various dates

Date	Lat	Date	Lat	Date	Lat
Jan 5	23°S	May 5	16°N	Sept 7	6°N
20	20°S	22	20°N	23	0°
Feb 2	17°S	June 7	23°N	Oct 3	4°S
19	12°S	21	23.5°N	24	11°S
Mar 5	6°S	July 6	23°N	Nov 7	16°S
21	0°	21	21°N	23	20°S
Apr 6	6°N	Aug 5	17°N	Dec 8	23°S
20	11°N	21	12°N	22	23.5°S

On March 5th, Sun shines over head on 6° South latitude (from the latitude table).

$\therefore$ Latitude of Delhi = 34° 43' - 6° = 28° 43'

Principle used: The following figures show the Sun's rays falling on the earth during summer and winter in the Northern hemisphere respectively.

O is the centre of the Earth. O' is any point on the equator, C is a point on the latitude at which the Sun is overhead, A is the place for which the latitude has to be found, AB is the refill, AD is the shortest shadow cast and DF and

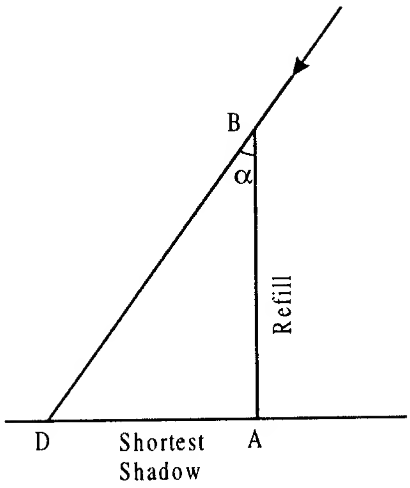


Fig. 55 a

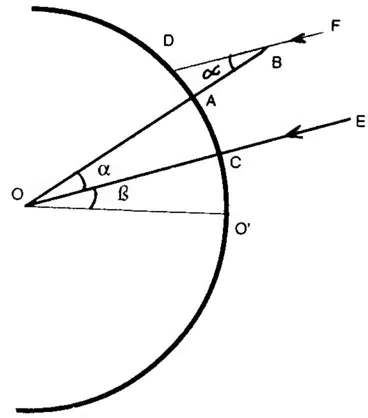


Fig. 55 b. Summer in the Northern Hemisphere

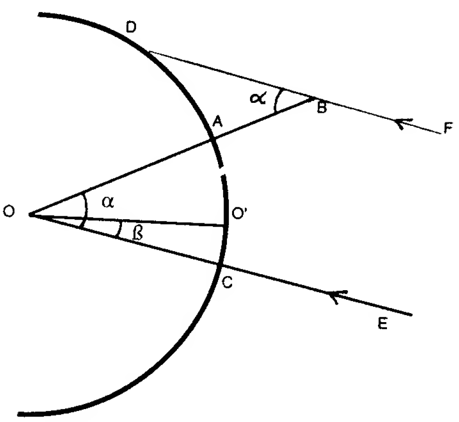


Fig. 55 C. Winter in the Southern Hemisphere

Table 9.2.1

NATURAL TANGENTS

Degrees	0' 0°.0	6' 0°.1	12' 0°.2	18' 0°.3	24' 0°.4	30' 0°.5	36' 0°.6	42' 0°.7	48' 0°.8	54' 0°.9	Mean Differences				
											1	2	3	4	5
0	00000	00175	00349	00524	00698	00873	01047	01222	01396	01571	29	58	87	116	146
1	01746	01920	02095	02269	02444	02619	02793	02968	03143	03317	29	58	87	116	146
2	.03492	03667	03842	04016	04191	04366	04541	04716	04891	05066	29	58	87	117	146
3	.05241	05416	05591	05766	05941	06116	06291	06467	06642	06817	29	58	88	117	146
4	-06993	07168	07344	07519	07695	07870	08046	08221	08397	08573	29	59	88	117	146
5	.08749	08925	09101	09277	09453	09629	09805	09981	10158	10334	29	59	88	117	147
6	.10510	10687	10863	11040	11217	11394	11570	11747	11924	12101	29	59	88	118	147
7	.12278	12456	12633	12810	12988	13165	13343	13521	13698	13876	30	59	89	118	148
8	.14054	14232	14410	14588	14767	14945	15124	15302	15481	15660	30	59	89	119	149
9	.15838	16017	16196	16376	16555	16734	16914	17093	17273	17453	30	60	90	120	150
10	.17633	17813	17993	18173	18353	18534	18714	18895	19076	19257	30	60	90	120	150
11	.19438	19619	19801	19982	20164	20345	20527	20709	20891	21073	30	60	91	121	152
12	.21256	21438	21621	21804	21986	22169	22353	22536	22719	22903	30	61	92	122	153
13	.23087	23271	23455	23639	23823	24008	24193	24377	24562	24747	31	61	93	124	155
14	.24933	25118	25304	25490	25676	25862	26048	26235	26421	26608	31	62	93	124	155
15	.26795	26982	27169	27357	27545	27732	27920	28109	28297	28486	31	63	94	125	157
16	.28675	28864	29053	29242	29432	29621	29811	30001	30192	30382	32	63	95	127	158
17	.30573	30764	30955	31147	31338	31530	31722	31914	32106	32299	32	64	96	128	160
18	.32492	32685	32878	33072	33266	33460	33654	33848	34043	34238	32	65	97	129	162
19	.34433	34628	34824	35019	35216	35412	35608	35805	36002	36199	33	66	98	131	164
20	.36397	36595	36793	36991	37190	37388	37588	37787	37986	38186	33	66	99	133	166
21	.38386	38587	38787	38988	39190	39391	39593	39795	39997	40200	34	67	101	134	168
22	.40403	40606	40809	41013	41217	41421	41626	41831	42036	42242	34	68	102	136	170
23	.42447	42654	42860	43067	43274	43481	43689	43897	44105	44314	34	69	104	138	173
24	.44523	44732	44942	45152	45362	45573	45784	45995	46206	46418	35	70	105	141	176

NATURAL TANGENTS

Degrees	0' $0^{0}.0$	6' $0^{0}.1$	12' $0^{0}.2$	18' $0^{0}.3$	24' $0^{0}.4$	30' $0^{0}.5$	36' $0^{0}.6$	42' $0^{0}.7$	48' $0^{0}.8$	54' $0^{0}.9$	Mean Differences 1	2	3	4	5
25	46631	46843	47056	47270	47483	47698	47912	48127	48342	48557	36	71	107	143	179
26	.48773	48989	49206	49423	49640	49858	50076	50295	50514	50733	36	73	109	145	182
27	.50953	51173	51393	51614	51835	52057	52279	52501	52724	52947	37	74	111	148	185
28	.53171	43395	53020	53844	54070	54296	54522	54748	54975	55203	38	75	113	151	188
29	.55431	55659	55888	56117	56347	56577	56808	57039	57271	57503	38	77	115	154	192
30	.57735	57968	58201	58435	58670	58905	59140	59376	59612	59849	39	78	118	157	196
31	.60086	60324	60562	60801	61040	61280	61520	61761	62003	62245	40	79	120	160	200
32	.62487	62730	62973	63217	63462	63707	63953	64199	64446	64693	41	82	123	164	205
33	.64941	65189	65438	65688	65938	66189	66440	66692	66944	67197	42	84	126	167	299
34	.67451	67705	67960	68215	68471	68728	68985	69243	69502	69761	43	86	129	171	214
35	.70021	70281	70542	70804	71066	71329	71593	71857	72122	72388	44	88	132	176	219
36	.72854	72921	73189	73457	73726	73996	74267	74538	74810	75082	45	90	135	180	225
37	.75355	75629	75904	76180	76456	76733	77010	77289	77568	77848	46	92	139	185	231
38	.78129	78410	78692	78975	79259	79544	79829	80115	80402	80690	47	95	142	190	237
39	.80978	81268	81558	81849	82141	82434	82727	83022	83317	83613	49	98	147	195	244
40	.83910	84208	84507	84806	85107	85408	85710	86014	86318	86623	50	100	151	201	252
41	.86929	87236	87543	87852	88162	88473	88784	89097	89410	89725	52	103	155	207	259
42	.90040	90357	90674	90993	91313	91633	91955	92277	92601	92926	53	107	160	214	268
43	.93252	93578	93906	94235	94565	94896	95229	95562	95897	96232	55	111	165	221	276
44	.96569	96907	97246	97586	97927	98270	98613	98958	99304	99652	57	114	171	229	286
45	1.0000	00350	00701	01053	01406	01761	02117	02474	02832	03192	58	118	177	237	296
46	1.03553	03915	04279	04644	05010	05378	05747	06117	06489	068062	61	123	184	245	307
47	1.07237	07613	07990	08369	08749	09131	09514	09899	10285	10672	63	127	191	255	319
48	1.11061	11452	11844	12238	12633	13029	13428	13828	14229	14632	66	132	199	205	331
49	1.15037	15443	15851	16261	16672	17085	17500	17916	18334	18754	69	138	207	276	344

NATURAL TANGENTS

Degrees	0' 0°.0	6' 0°.1	12' 0°.2	18' 0°.3	24' 0°.4	30' 0°.5	36' 0°.6	42' 0°.7	48' 0°.8	54' 0°.9	Mean Differences 1	2	3	4	5
50	1.19175	19599	200	20451	20879	21310	21742	22176	22612	23050	72	143	216	288	359
51	1.23490	23931	24375	24820	25268	25717	26169	26622	27077	27535	75	150	225	300	375
52	1.27994	28456	28919	29385	29853	30323	30795	31260	31745	32224	78	157	235	314	392
53	1.32704	33187	33673	34160	34650	35142	35637	36134	36633	37134	82	164	247	329	411
54	1.37638	38145	38653	39165	39679	40195	40714	41235	41759	42280	86	172	259	345	431
55	1.42815	43347	43881	44418	44958	45501	46046	46595	47146	47700	91	181	272	362	453
56	1.48256	48816	49378	49944	50512	51084	51658	52235	52816	53400	95	191	286	382	477
57	1.53987	54576	55170	55767	56366	56969	57575	58184	58797	59414	100	201	302	403	504
58	1.60033	60657	61283	61914	62548	63185	63826	64471	65120	65772	106	213	319	426	533
59	1.66428	67088	67752	68419	69091	69766	70446	71129	71817	72509	113	226	339	452	564
60	1.73205	73905	74610	75319	76032	76749	77471	78198	78929	79665	120	240	360	481	600
61	1.80405	81150	81900	82054	83413	84177	84946	85720	86500	87283	128	255	383	511	639
62	1.88073	88867	89667	90472	91282	92098	92920	93746	94579	95417	136	273	409	546	683
63	1.96261	97111	97967	98828	99695	2.00569	2.01449	2.02335	2.03227	2.04125	146	292	438	584	731
64	2.05030	05942	06860	07785	08716	09654	10600	11552	12511	13477	157	314	471	629	786
65	2.14451	15432	16420	17416	18419	19430	20449	21475	22510	23553	169	338	508	677	846
66	2.24004	25663	26730	27806	28891	29984	31080	32197	33317	34447	183	366	549	732	915
67	2.35585	36733	37891	39058	49235	41421	42618	43825	45043	46270	199	397	596	795	994
68	2.47509	48758	50018	51289	52571	53865	55170	56487	57815	59156	Mean differences. came to				
69	2.60509	61874	63252	64642	66046	67462	68892	70335	71792	73263	be sufficiently accurate.				
70	2.74748	76247	77761	79289	80833	82391	83965	85556	87161	88783					
71	2.90421	92076	93748	95437	97144	98868	3.00611	3.02372	3.04152	3.05950					
72	3.07768	09606	11464	13341	15240	17159	19100	21063	48	25055					
73	3.27085	29139	31216	33317	35443	37594	39771	41973	44202	46458					
74	3.48741	51053	53393	55761	58160	60588	63048	65538	68061	70616					

NATURAL TANGENTS

Degrees	0' 0°.0	6' 0°.1	12' 0°.2	18' 0°.3	24' 0°.4	30' 0°.5	36' 0°.6	42' 0°.7	48' 0°.8	54' 0°.9	Mean Differences 1	2	3	4	5
75	3.73205	75828	78485	81177	83906	86671	89474	92316	95196	98117					
76	4 01078	04081	07127	10216	13350	16530	19756	23030	26352	29724					
77	4.33148	36623	40152	43735	47374	51071	54826	58641	62518	66458					
78	4.70403	74534	78673	82882	87162	91516	95945	5.00451	5.05037	5.09704					
79	5.14455	19293	24218	29235	34345	39552	44857	50264	55777	61397					
80	5.67128	72974	78938	85024	91236	97576	6.04051	6.10664	6.17419	6.24321					
81	6.31375	38587	45961	53503	61220	69116	77199	85475	93952	7.02637					
82	7.11537	20661	30018	39610	49465	59575	69957	80622	91582	8.02848					
83	8.14435	26356	38625	51259	64275	77689	91520	9.05789	9.20516	9.35724					
84	9.51436	9.6768	9.8448	10.019	10.199	10.385	10.579	10.780	10.988	11.205					
85	11.430	11.664	11.909	12.163	12.429	12.706	12.996	13.300	13.617	13.951					
86	14.301	14.669	15.056	15.464	15.895	16.350	16.832	17.343	17.886	18.464					
87	19.081	19.740	20.446	21.205	22.022	22.904	23.859	24.898	26.031	27.271					
88	28.636	30.145	31.821	33.694	35.801	38.188	40.917	44.066	47.740	52.081					
89	57.290	63.657	71.615	81.847	95.489	114.60	143.24	190.98	286.48	572.96					
90	00														

CE are the parallel Sunrays. (fig. 55a, 55b and 55c).
$\angle DBO = \angle BOC = \alpha$ (interior alternate angles).

latitude of C = $\angle COO' = \beta$
Latitude of A = $\angle AOO'$
Summer in the Northern hemisphere (fig .55 a)
$\angle AOO' = \angle AOC + \angle COO' = \alpha + \beta$
Winter in the Northern hemisphere (fig. 55 b)
$\angle AOO' = \angle AOC - \angle COO' = \alpha - \beta$

Project III

To find the time using it as a Sundial

The same model with a small modification can be used as a Sundial too.

Process : Steps involved are

Step1:Paste the Sundial on the cardboard such that the centre of the dial and the centre of the cardboard coincide.

Step2:The refill should face True North and the cardboard should be placed such that it makes an angle of colatitude (90° - latitude of the place), with the plane.

Step3:After the model is set up, the position at which the shadow of the refill is cast tells you the time.

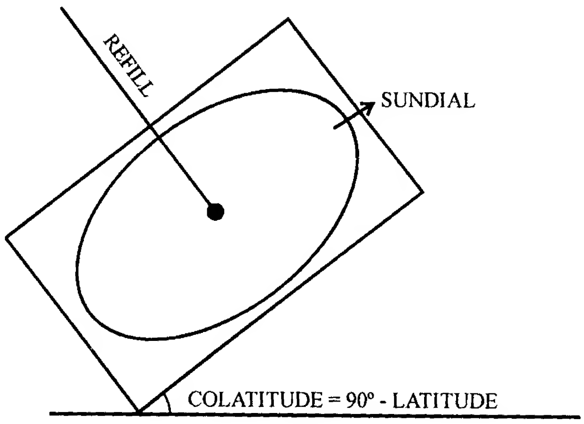


Fig. 56

Project IV

To Prove that Earth's Axix is Tilted at an Angle to the Vertical

The same model can be used for this purpose also.

Process: Steps involved are

Step1: Place the cardboard in the same place and position.

Step2: Observe the time at which the shortest shadow is cast on a particular day every week. The shadow would be shortest when it crosses the N-S line.

Step3: You will find that the shortest shadow does not necessarily occur exactly at noon.

If the axis of the earth were perpendicular to the plane of its orbit, the shortest shadow would occur exactly at 12 noon every day.

Project V

To study the length of the shortest shadow on different days of the year

Materials Required: For this project, the materials which were used for projects I to IV can be used.

Process :The steps involved are:

Step1:Set up the model as was done for Project - I

Step2:Mark the N-S line on it.

Step3:Mark the shortest shadow on a particular day of each month. Follow this procedure for all the 12 months.

Step4: Tabulate the results as shown below :

Date	Jan	Feb	March	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Shadow length												

You can choose any date. But as the equinox falls on March 21st, summer solstice on 21st of June, autumnal equinox on September 23rd and winter solstice on 22nd of December, you can choose 21st of each month or a date as close as possible to 21st.

Step5: Plot the shadow length against the date on a graph sheet. Plot the date along the X-axis and the shadow length on the Y-axis. Use a centimeter graph sheet and take the scale as 1 cm. on graph to represent 1 cm. of shadow length. (fig.57)

Step 6: Study the graph thus obtained.

Find out : i.When is the shadow shortest? Why?

ii. When is the shadow longest? Why?

iii. When are the lengths of shadows equal? Why?

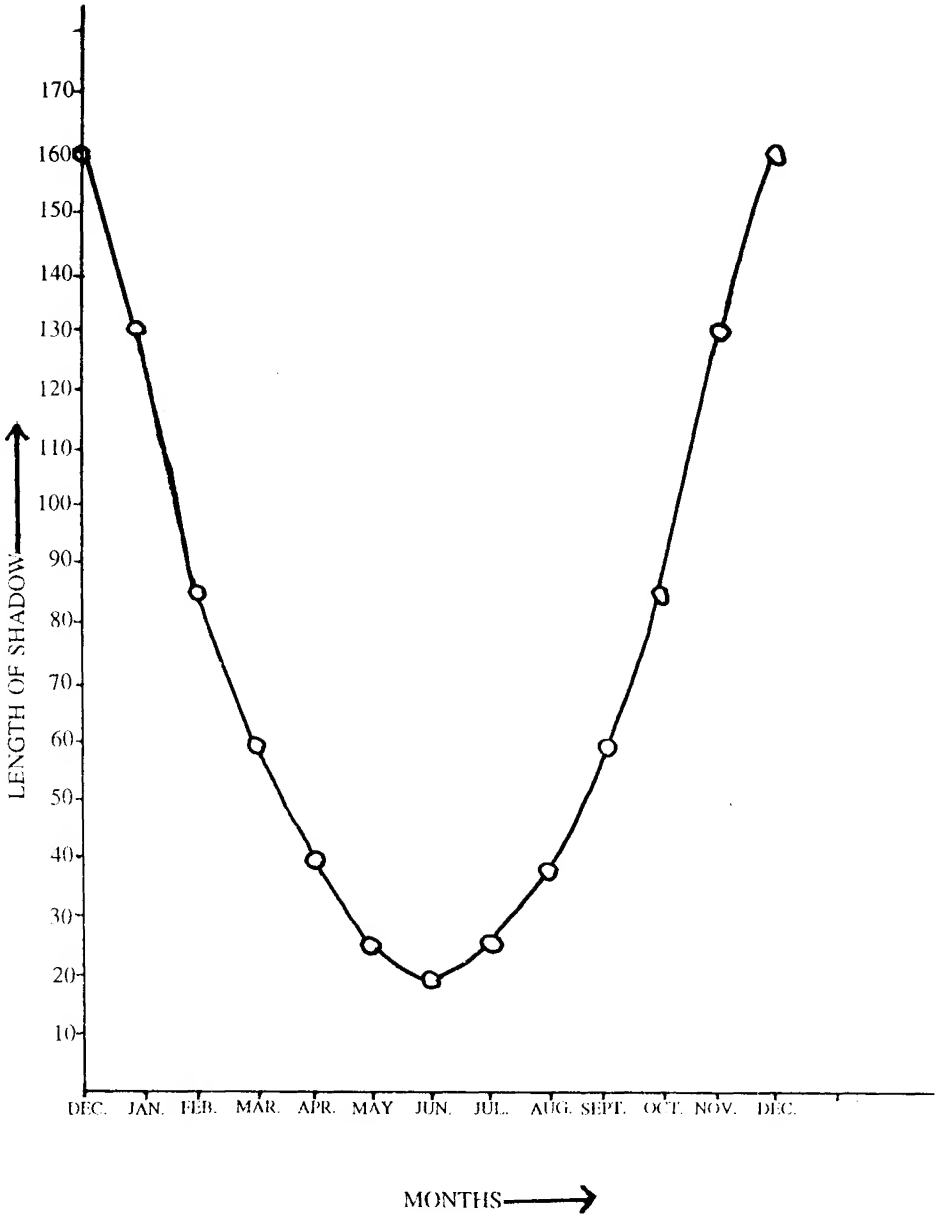

170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
LENGTH OF SHADOW
DEC. JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEPT. OCT. NOV. DEC.
MONTHS

Fig. 57

Model 2

PROJECT - VI

Sundial:(Horizontal) This model can be used for finding the time with the help of the Sun.

Materials required:

i. 20 cms x 20 cms thick cardboard
ii. White paper of the same size
iii. Instrument box
iv. Scissors and glue

What to do:

Step1: Paste the white paper on the cardboard and cut out a 15 cms x 15 cms square. mark the centre of the square.

Step2: With the point as centre, draw concentric circles of radii 5.5 cms. and 7.5cms. respectively. Divide the circles as shown in the figure to get the dial (fig. 58) or trace out the sundial from the figure, cut it and paste it on the cardboard.

Step3: Cut out a right angled triangle from the remaining cardboard. The base of the triangle should be = 7.5 cms. and the base angle equal to the latitude of the place. This triangle is called the Gnomon(fig 59)

Step4: Make a slit from the centre to the edge of the Sundial as shown. Fix the triangle in the slit.

Step5: Place the Sundial on a level surface such that the edge of the triangle faces True North. The place where the shadow of the edge of the gnomon falls on the face of the dial will give you the time.

Principle used : As the apparent path of the Sun i.e. the Ecliptic is curved and not straight, the circle is not divided equally.

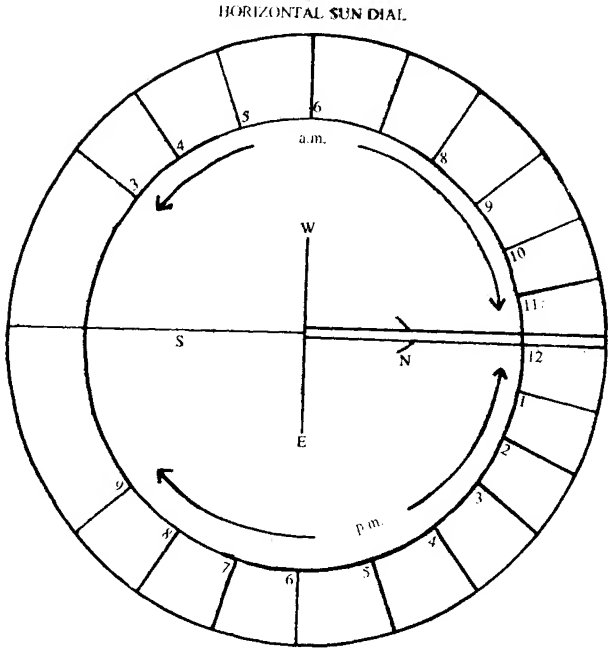
As the Sun moves through 15° each hour, the shadow would also move through 15" each hour, if it falls on a curved surface (parallel to the ecliptic).

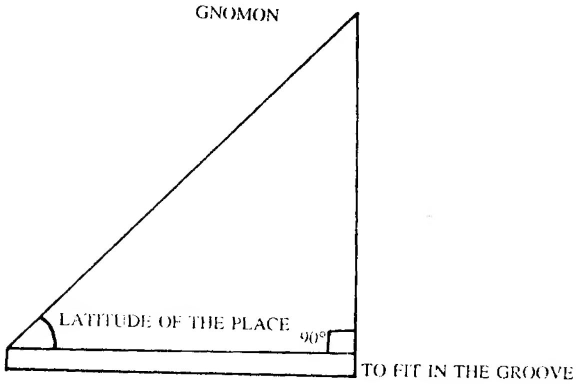
Extension Project :

i. Using a clock find out how accurate is the Sundial.

ii. Find out the least time interval which can be measured with the Sun dial.

Investigative project : Note the time every week at a particular time. You may add or subtract something to find the correct time. Find out why these corrections need to be made to get the accurate time.


HORIZONTAL SUN DIAL
a.m.
p.m.
W
S
N
E
6
5
4
3
8
9
10
11
12
1
2
3
4
5
6
7
8
9


GNOMON
LATITUDE OF THE PLACE
90°
TO FIT IN THE GROOVE

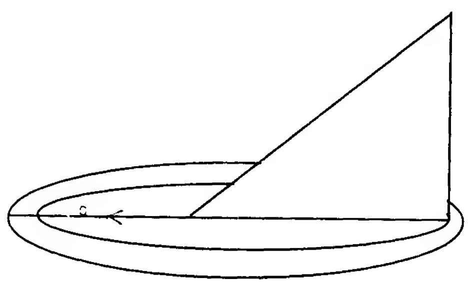


Fig. 58 & 59

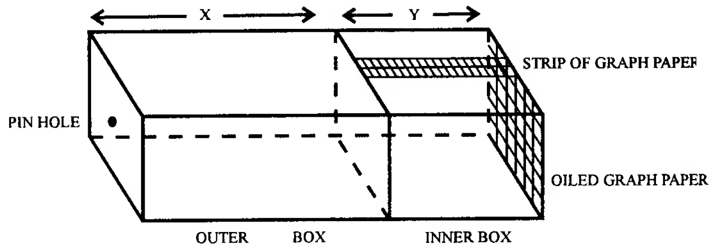
Model 3

PROJECT - VII

Pin Hole Camera: This modified pin hole camera can be used to find the diameter of the Sun.

Material Required:

i. Sheet of cardboard or 2 rectangular (cuboidal) boxes which slide over one another
ii. paper for covering the boxes.
iii. Oiled graph sheet - 1 no. (small), graph strip
iv. Cellophane tape and glue
v. Black paint



PIN HOLE CAMERA

Fig. 60

Process: The steps involved are:

Step1: Cover the 2 boxes with paper or fold the card board in the form of boxes and cover them with paper

Step2: Paint the inside of the 2 boxes black.

Step3: In the bigger box, keep one side open and cover the other side with paper and make a pin hole (of diameter 1 mm.) at the centre. Measure the length of this box. Let this be = X cm.

Step4: Keep one side of the smaller box open and cover the other side with oiled graph paper. Paste a thin strip (1cm width) of graph paper on the smaller box along its length.

Step5: Slide the bigger box over the smaller one. Hold the camera such that the pin hole faces the Sun. Move the smaller box, so that a clear image of the Sun is formed on the oiled graph paper.

Step6: Note down the diameter of the Sun's image on the graph paper. Let this be Z cm.

Step7: Note down the length of the smaller box which is outside the bigger box from the thin graph strip. Let this length be Y cm.

Step8: Calculation : I/O=V/U,
where I is the size of the image (Z cm.)
O is the size of the object (diameter of the Sun).
V is the distance of the image from the pin hole (X + Y) cm.
U is the distance of the object from the pin hole
= Distance between the Sun and the Earth = 1.5×10^{13} cms.

$$\text{Diameter of the Sun} = \frac{1.5 \times 10^{13} \times Z \text{ cm}}{X+Y}$$

PROJECT - VIII

Model 4

Star Clock: To find the time using the stars. This model is also called NOCTURNAL.

Materials required:

i. White cardboard - 30 cms. x 30 cms.
ii. Transparent plastic sheet - 30 cms. x 30 cms.
iii. Instrument Box.
iv. Scissors and glue
v. Paper fastener

Process : It involves the following steps :

Step 1 : Draw the figs. 61, 62, and 63 on the cardboard and cut them out.
Step 2 : Draw the figs. 61 and 62 on the plastic sheet and cut them out.
Step 3 : Mark the inner and the outer dial as shown.
Step 4 : Paste the cardboard fig. 61 and 62 on plastic cut outs of 61 and 62 respectively.
Step 5 : Keep the arm 63, the inner dial and the main dial one below the other and use the paper fastener to assemble them as shown in Fig. 64.

Method of using:

Step 1 : Hold the star clock vertically and make the pointer of the inner dial coincide with the date and month on the outer dial.
Step 2 : Adjust the position of the star clock, so that the centre of the star clock coincides with the pole star.
Step 3: Move the arm so that the lower edge of the arm just joins the pointer stars of Ursa Major. The reading on the inner dial gives the time.

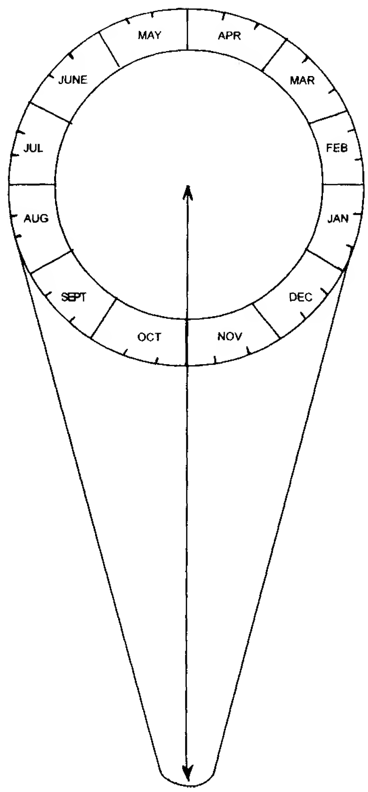


Fig. 61 The Main Dial

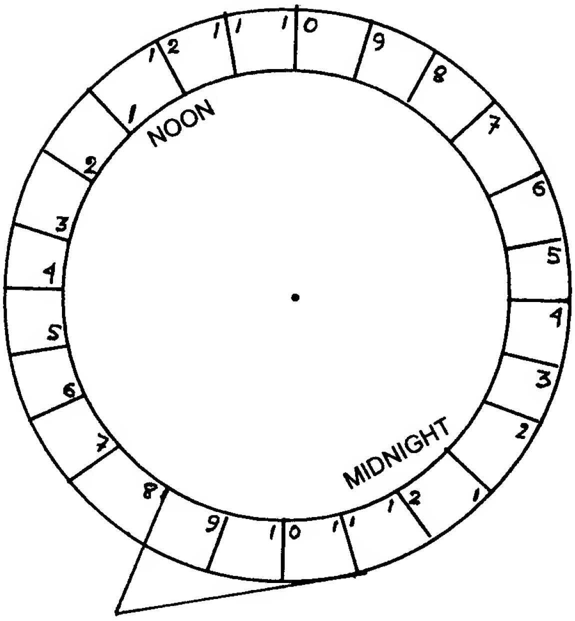


Fig. 62 Inner Dial

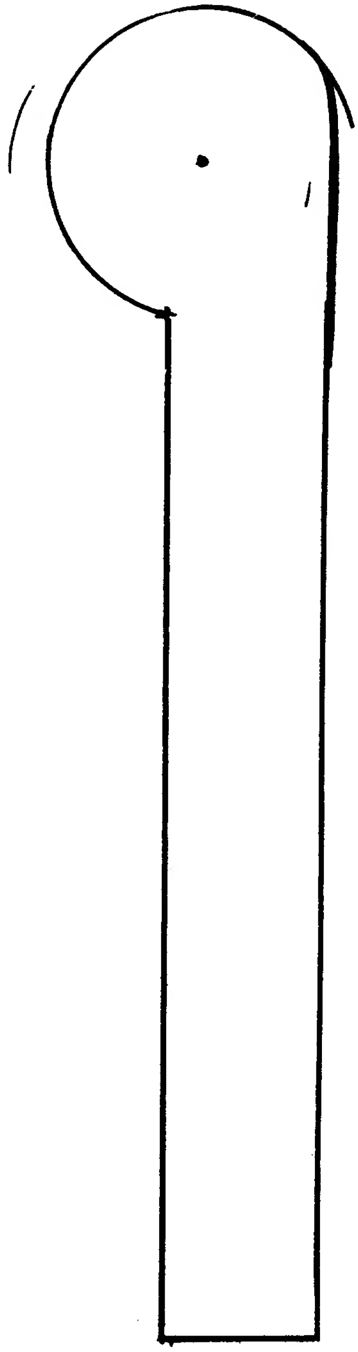


Fig. 63 Arm

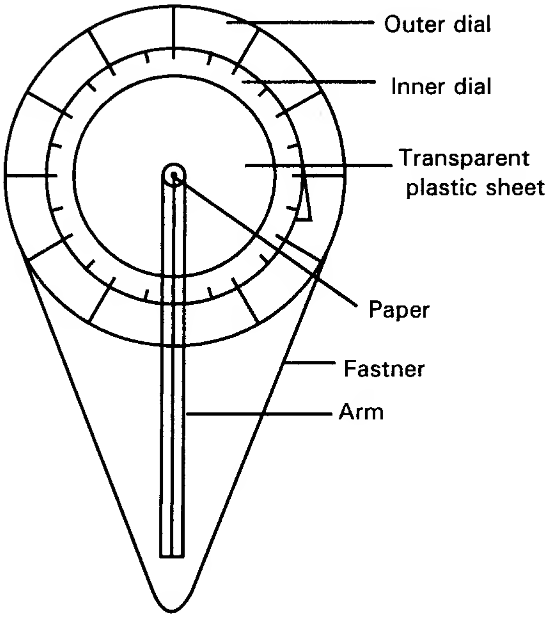


Fig. 64

Model 5

PROJECT - IX

Transit: This is used to find the angular separation between 2 heavenly bodies like stars.

Material required:

i. Thin white cardboard - 30 cms. x 30 cms.
ii. Scissors and glue.
iii. Instrument box.

Process: The following steps are involved :

Step 1 : Draw the fig. 61 on the cardboard and cut it out.
Step 2 : Make a centimeter scale of length 30 cms and width 4 cm.
Step 3 : Fold the figure along XY and past AB over PQ leaving the gap CD.
Step 4 : Insert the cardboard scale through CD and RS.

Method of using:

Step 1 : Keep your eye at the end of the scale as shown in Figs. 62 and 63, adjust the Transit such that the 2 heavenly bodies just touch the inner most edges L and M or the middle ones G and H or the outer most edges E and F.

Step 2 : Now take the reading on the scale, if the inner most edges L and M are used as reference, then

$\text{Tan } \theta = 1/2 \times [\text{LM}/\text{Reading on the scale}]$

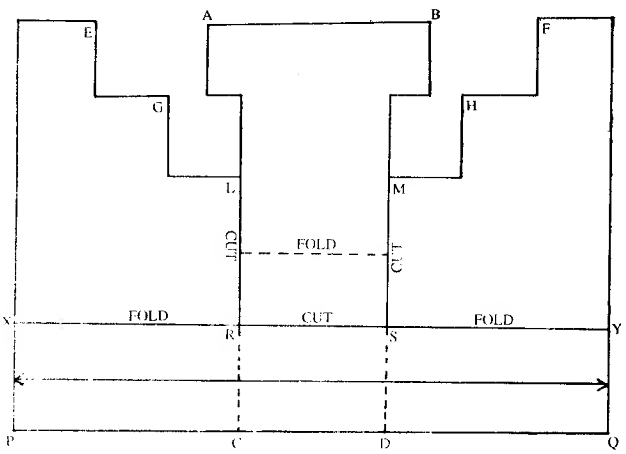
$\text{Tan } \theta = 1/2 \times [4/\text{Reading on the scale}]$

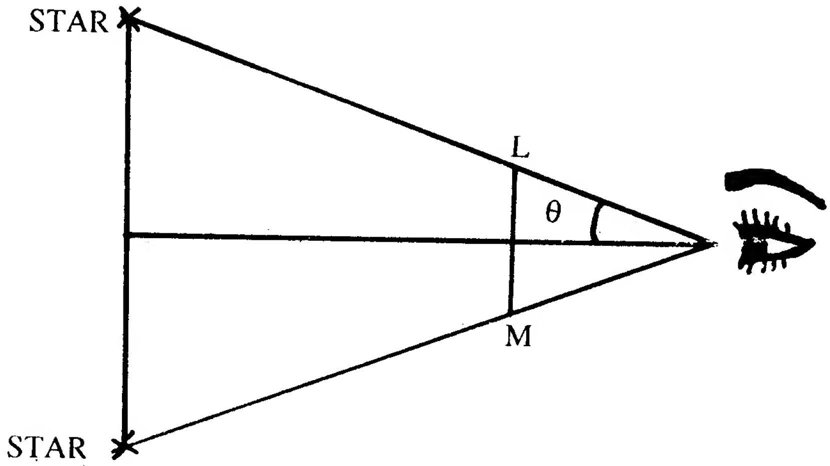
$= 2/\text{Reading on the scale}$

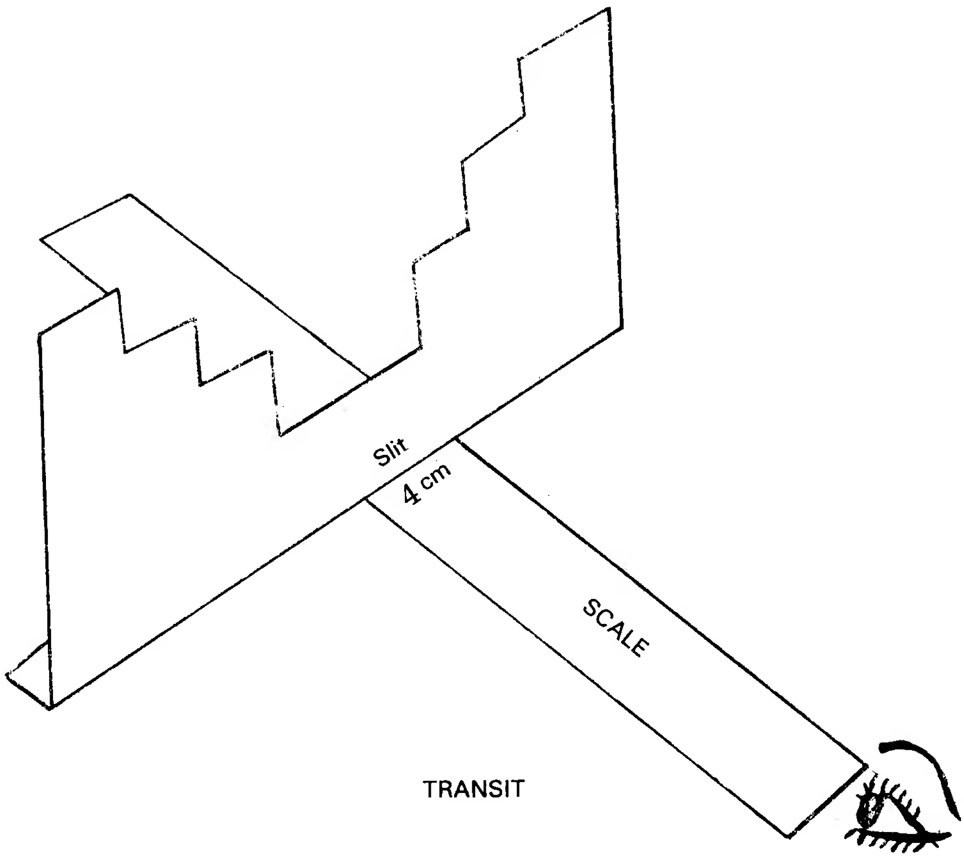
Step 3 : Find the value of θ from the Tangent table. Angular separation between the stars = 2 x θ.

Investigative Experiment:

Make the observations at different times during the night and check whether the angular separation between any 2 celestial bodies remains constant or not.







TRANSIT

Fig. 66 & 67

Model 6

PROJECT - X

Altitude Meter: To find the altitude or height of heavenly bodies.

Materials required:

i. Thick lid (15 cms. x 15 cms. approx.) of cardboard box.
ii. Thick stiff cardboard piece of length 12 cms and width 4 cms.
iii. Plastic protractor
iv. Paper fastener.
v. White stiff paper of length 10 cms. and width 5 cms.
vi. Twine thread and a small weight.
vii. Thumb pin
viii. Instrument box.
ix. Scissors and glue

Process: The following steps are involved.

Step1: Make the tube with the stiff paper by rolling it over a pencil and stick it with glue

Step2: Make a small slit, 4 cms. long in the centre of the cardboard lid and fix the 12 cms. long cardboard in the slit.

Step3: Make a small hole with the help of a heated nail in the protractor at the point where all the lines meet.

Step4: Make a hole at the top of the cardboard strip and fix the protractor to the cardboard strip with the help of the paper fastener, so that the protractor moves freely.

Step5: Stick the paper tube on the protractor along its straight edge.

Step6: Make a plumb line with the thread and small weight. Fix this to the opposite side of the cardboard from the protractor with the help of a thumb pin. (fig. 64 and 65).

Process :

Step1: Place the instrument on a level surface, so that the tube fixed to the protractor faces the direction of the star to be observed.

Step2: Now keep your eye on one side of the tube and tilt the protractor till you can observe the particular star through the tube. If the reading on the protractor is θ , the altitude of the star = $(90-\theta)^0$.

Investigative Experiment:

i. Use the altitude meter to determine the variation in the altitude of moon with change in time.

ii. Try the same experiment with a star also. Note down your observations and trace the path of the celestial bodies.

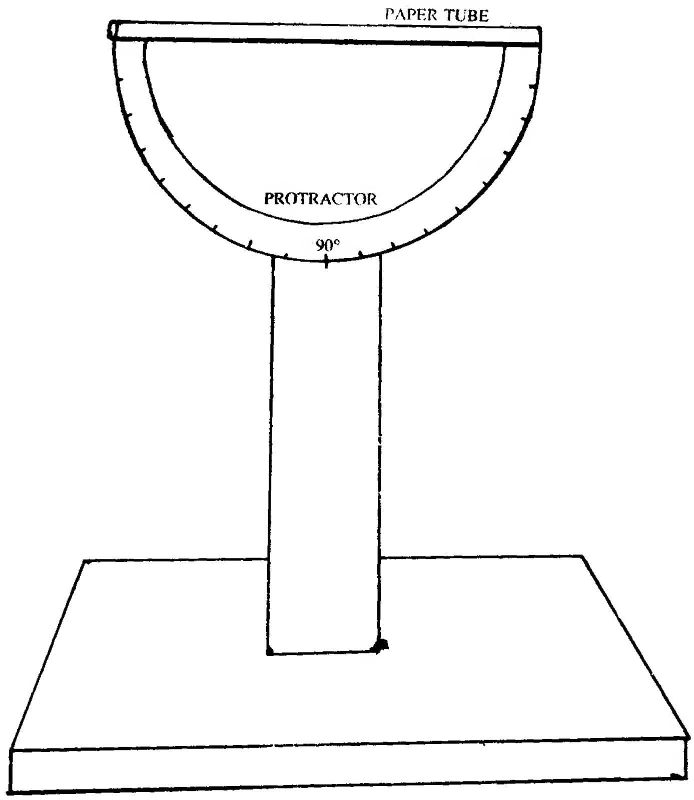


Fig. 68 Altitude Meter

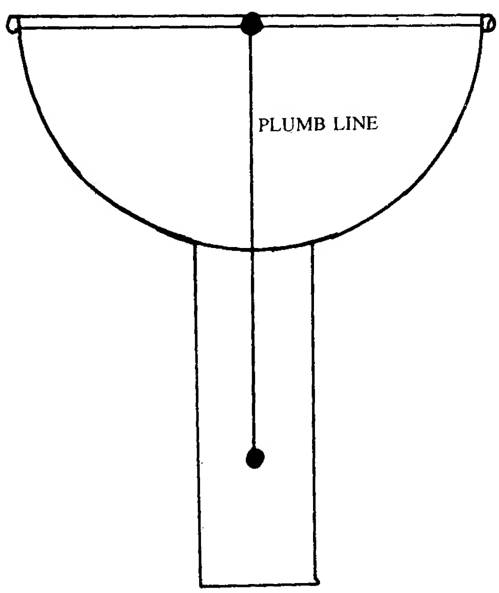


Fig. 69 Backside of the Meter

Model 7

PROJECT - XI

The Sun Camera

To observe the Sun-spots by using a Sun-camera.

Materials Required:

i. A cardboard cylindrical tube 175 cms. long and diameter slightly smaller than that of the lens. The tube should be blackened from inside.

ii. A shorter cardboard tube which slides over the other tube of length 75cms. This tube should also be blackened from inside.

iii. A convex lens 0.5D and focal length 2ms.

iv. Oiled tracing paper

v. Adhesive

Process: The steps involved are :

Step1. Fix the lens to one end of the longer and thinner tube using adhesive.

Step2. Fix the oiled tracing paper to the broader tube, not at the opening, but 5 to10 cm. inside the tube. This is done to reduce the blurring of image due to diffused light from outside.

Step3. Slide the broader tube over the longer tube till a clear image of the Sun is formed on the tracing paper. You can observe some dark spots on the image of the Sun. These are the images of the Sun spots. (fig.70)

Caution: Do not place your eye near the tracing paper while observing the Sun.

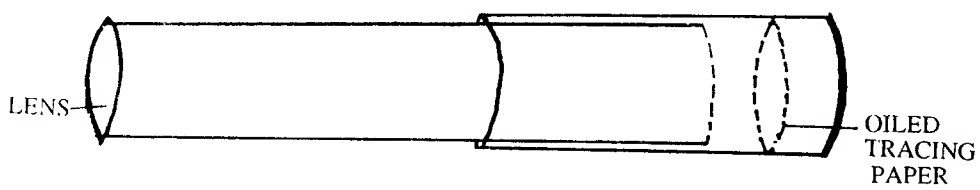


Fig. 70

Bringing Heavenly Bodies Nearer

Refractor Telescope:

An astronomical refracting telescope consists of two convex lenses. The convex lens of bigger focal length (object lens) gives a real, diminished inverted image of the object while the convex lens of shorter focal length (eye piece) works as magnifier.

Materials Required:

Corrugated cardboard sheet (from discarded box) : two convex lenses of 20 cms and 10 cms focal length and adhesive

Process:

Step1. Make a cardboard tube of length of 25 cms and diameter slightly shorter than the object lens.

Step2. Stick the object lens to one end of the tube using the adhesive.

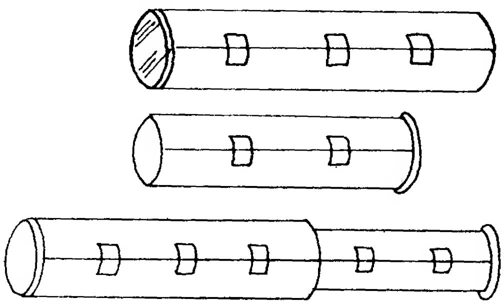


Fig. 71

Step3. Make another tube of length of about 12 cms. with diameter slightly less than the first tube.

Step4. Fix the second convex lens to this tube using the adhesive.

Step5. Put the second tube in the first tube and make sure that the second one does slip down into the first one.

Step6. Look at the distance object using the telescope and move the eye piece tube so that you get a distinct image.

Special material sources:

Convex lenses can be bought from the stationery shop, optician's shop or a scientific goods supplier's shop.

Extension Project:

1. Look at the Moon's craters through your telescope.
2. Look at some stars and visible planets using the telescope

Investigative Projects:

1. Find the magnifying power of the telescope
2. By getting the convex lenses of different focal lengths investigate how the magnifying power changes with the focal lengths of lenses.

PROJECT - XII

Model 8

Reflector Telescope

It will be a nice idea to have a closer look at the stars with the help of a concave mirror and a convex lens. The concave mirror in a reflecting telescope produces a real diminished image which is magnified by convex lens.

Materials Required:

i. Wooden box (10 cms x 10 cms x 4 cms) - 1
ii. Wooden rod (20 cms long, 2 cms diameter) - 1
iii. Wing nuts and screw- 2 pairs
iv. Wood screws - 2
v. Convex lens of focal length - 7.5 cms.
vi. Concave mirror of focal length - 20 cms.
vii. Cardboard - 15 cms. x 15 cms.

Process:

Step1. Mount the concave mirror on the wooden box.
Step2. The mirror is mounted on the side of the box using the wing nut and screw.
Step3. Make the cardboard tube and fix the convex lens on it.
Step4. Mount the tube on the wooden rod at 20 cms. height.
Step5. Look through the tube during the night time to look at the stars in the sky.

Special material sources

Convex lens and concave mirror can be bought from the optician's shop or scientific supplier's shop.

Extension Projects:

1. Look at the Moon's craters through your reflecting telescope and map a few craters.
2. Look at some stars and visible planets using reflecting telescope.

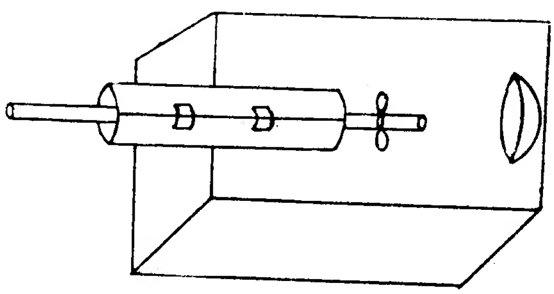


Fig. 72

Model 9

PROJECT - XIII

Discovering weightlessness in free-fall: Astronauts have to undergo weightlessness in space. On earth, weightlessness can be simulated in the free-fall situation. let us discover weightlessness in the following experiments.

Materials Required

i. Cycle spoke or knitting needle - 1
ii. String or twine - 1m
iii. Stone (about 200 gms. weight) - 1

Process:

Step1. Bend the spoke or knitting needle to make a U-shape frame out of it.
Step2. Tie a loose string to the two free ends of the U-frame
Step3. Tie the stone piece to another string.
Step4. Tie the frame string and the stone carrying string together as shown in fig.
Step5. Hold the free end of the stone carrying string in hand
Step6. Leave the string to allow the system to fall down.
Step7. What do you observe ?

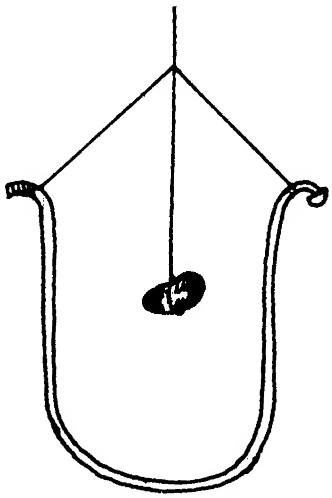


Fig. 73

Other Vigyan Prasar/NCSTC Publications

Myths & Legends Related to Eclipses*
N.C. Rana ISBN: 81-7480-006-9
pp: 61 Rs.21

Total Solar Eclipse :
*Answers to All Your Questions**
Narender K. Sehgal & Sandip Bhattacharya
ISBN: 81-7480-007-7
pp: 37 Rs.12

Rahu Ketu Ki Khoj
Rakesh Popli ISBN: 81-7480-009-3
pp: 34 Rs.12

Khoya Hua Janam Din
Rakesh Popli ISBN: 81-7480-008-5
pp: 56 Rs. 20

Akash Darshan Ka Anand
Rakesh Popli ISBN: 81-7480-010-7
pp: 75 Rs. 25

Leaf Zoo*
Arvind Gupta ISBN. 81-7480-060-3
pp. 24 Rs. 20

Pumps from the Dump*
Suresh Vaidyarajan and Arvind Gupta
ISBN: 81-7480-063-8
pp : 30 Rs.20

Toy Joy*
Arvind Gupta and Ramesh Kothari
ISBN: 81-7480-064-6
pp: 34 Rs.20

Let's Put Things Together *
Lalit Kishore and Anwar Zafri
ISBN:81-7272-005-X
pp: 69 Rs.25

Seeing is not always believing*
ISBN : 81-7480-045-X
pp: 128 Rs. 65

Jano Aur Boojho
Baldev Raj Davar
ISBN:81-7272-007-6
pp: 12 Rs:05

Kahani Maap -Tol Ki
Baldev Raj Davar
ISBN: 81-7272-010-6
pp: 45 Rs. 20

The Chemical History of a Candle*
Michael Faraday
ISBN : 81-7480-002-6
pp: 146+xx Rs. 35

Soap Bubbles
*and the Forces Which Mould Them**
C.V. Boys
ISBN: 81-7480-001-8
pp: 109+xiv Rs.30

My Friend Mr Leakey
J.B.S. Haldane
ISBN: 81-7480-001-8
pp: 109 + xix Rs. 30

Square Pegs in Round Holes
Ravindra Keskar
ISBN: 81-7480-048-4
pp: 71 Rs. 50

Chamatkar Ka Rahasya
Dr. Vijay Gupta
ISBN: 81-7480-069-7
pp: 43 Rs. 25

Iodine Sainik
Dr. Vijay Gupra
ISBN: 81-7480-067-0
pp: 50 Rs. 40

Gilas Se Khel Karke Dekho
Pratapmal Devpura
ISBN: 81-7480-070-0
pp: 73 Rs. 35

Kyon Aur Kaise?*
Pratho Ghosh, Dipanker Home,
Narender K. Sehgal
ISBN: 81-7480-066-2
pp: 111 Rs. 100

Science and Everyday Life
J.B.S. Haldane
ISBN: 81-7480-088-3
pp: 226 Rs. 55

Fun and Science at Home
Jyoti Bhansali and L. S. Kothari
ISBN: 81-7480-078-6
pp: 130 Rs. 75

The Insect World of J. Henri Fabre
ISBN: 81-7480-087-5
pp: 178 Rs. 45

The Story of Physics*
T. Padmanabhan
ISBN: 81-7480-080-8
pp: 52 Rs. 40

Charging the Human Battery
D.Porichha
ISBN: 81-7480-083-2
pp: 120 Rs. 45

***** *(available in Hindi & English)***

ISBN : 81-7480-072-7

Rs.45/-

Vigyan Prasar
C-24 Qutab Institutional Area
New Delhi -110 016